RETHINKING THE BATHTUB FOR UNIVERSAL USE

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by

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RETHINKING THE BATHTUB FOR UNIVERSAL DESIGN

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SUMMARY

Body cleansing is an integral part of people's everyday life. Between five and seven percent of people over the age of 65 experience problems when using the bathroom. Some investigators have postulated that disability in older persons can further occur when there is a gap, mismatch, or poor fit between personal capabilities and environmental demands. Current bathing fixtures do not support people with limited ability, and so the current bathing environment perpetuates bathing disability. Furthermore, because assistive bathing technology is meant for one particular user, it can impede other users when they need to bathe. A consequence of this is that the assistive bathing technology could be abandoned. The purpose of this study is to design and evaluate a bathtub for body cleansing regardless of an individual's physical ability and allow for all stakeholders to use the tub within the same space.

CHAPTER 1

INTRODUCTION

Problem Statement

Body cleansing is an integral part of people's everyday life. It is the act of cleansing oneself for the physiological purpose of cleaning away accumulated waste materials, dead skin, and preventing irritations or rashes that might otherwise lead to infection (Ahluwalia, Gill, Baker, & Fried, 2010; Mullick, 1993). Body cleansing is done for a variety of reasons including odor concerns, a social expectation to bathe, habitual activity, the relaxation and producing the feeling of well-being (Ahluwalia et al., 2010; Kira, 1976). It is a process that consists of eight subtasks: obtaining and using supplies, taking off clothes, turning on water and adjusting the temperature, getting into the bathing position, washing whole body, leaving the bathroom position, drying whole body, and getting dressed (Naik, Concato, & Gill, 2004).

Between five and seven percent of people over the age of 65 experience problems when using the bathroom (Murphy, Gretebeck, & Alexander, 2007b). The process of bathing can provide both mental and physical difficulty for older adults, and be one of the most stress and agitating tasks for those receiving dementia care (Kovachand Meyer-Arnold, 1996).

Older adults with bathing disabilities are more likely to experience accidents and serious injury requiring hospitalization (Ostbye et al, 2004) and skilled nursing care (Brody et al, 1997) and is one of the first activities of daily living skills (bathing, dressing, transferring from a chair, and walking inside the home) lost in a nursing home population (Cohen-

Mansfield et al., 1995; Dunlop et al., 1997). Those with bathing difficulty represent an intermediate disability group (between complete dependence and independence with bathing) in terms of physical performance, subsequent healthcare utilization, and death (T M Gill, Robison, & Tinetti, 1998). Naik noted that some investigators have postulated that disability in older persons occurs when there is a gap, mismatch, or poor fit between personal capabilities and environmental demands (as cited in Verbrugge & Jet, 1994). Current bathing fixtures do not support people with limited ability, and so the current bathing environment perpetuates bathing disability.

The purpose of this study is to design and evaluate an innovative environment that will support body cleansing regardless of an individual's physical abilities. This study's first aim is to establish design criteria based on literature review, prior art, and analysis of existing online videos of people with disabilities using existing fixtures. The second aim is to design a tub that fits the design criteria, the third aim is to evaluate the design with expert interviews, and the final aim is to conduct usability testing and refine the design.

CHAPTER 2

BACKGROUND

Literature Review

The bathroom is an integral part of people's everyday life. Bathing can be considered a ritual that includes cleansing and relieving one's self. As people age there are physical and cognitive issues that make the basic functions of a bathroom difficult to perform. In fact, between five and seven per cent of people over the age of 65 experience problems when using the bathroom (Weiner, 1990; Murphy, 2007). Those who have bathroom disability are more likely to experience accidents and serious injury requiring hospitalization (Ostbye, 2004) and skilled nursing care (Brody, 1997). A study conducted at Sheffield Hallam University in the UK, reported that users observed that the height of the toilet, sink, bath and shower frequently caused problems for at least one member of the household (Burton 2011).

Injuries Related to Bathing

Injuries in the bathtub are also concerns, and can result in hip fractures and hospital admissions from sharp protruding fixtures, lack of support surfaces, and hard slippery surfaces which can cause falls. Physical issues such as having poor grip strength or difficulty reaching fixtures can cause extension that can also lead to falls (Kira, 1976; Mullick, 1993).

Defining Cleansing and Bathing Disability

Essential cleaning procedures include wetting, soaping, massaging, and rinsing. Bathing consists of three components: getting out and in, relaxing (major sub activity), and cleansing

which includes wetting, soaping, massaging, and rinsing (Kira, 1976). Cleansing can be done in several forms, including showering, bathing (tub), and sponge bath (sink)(Naik et al., 2004; Namazi & Johnson, 1996). Subtasks include: obtaining and using supplies, removing clothes, turning on water (adjusting temp), getting into bathing positions, washing whole body, leaving bathing position, drying whole body, and getting dressed (Naik et al., 2004). Bathing disability is defined as the inability to wash and dry one's whole body without personal assistance (Thomas M. Gill, Guo, & Allore, 2006) or having difficulty washing and drying the whole body (Naik et al., 2004).

Independence and Assistive Bathing

"When people are unable to perform these basic personal care tasks, they become dependent on help from either informal (family members or friends) or formal (paid) caregivers" (Hughes & Manheim, 1997). Assistive bathing can be divided into two distinct categories of personal assistance (a person helping with the task) and assistive technology (defined as special aids and devices; may also be referred by other studies as equipment assistance or environmental adaptations). Potentially valuable assistive technology (eg. grab bars, bath mats, etc) are absent from the homes of many older adults with bathing disability and may be particularly under utilized by older adults reporting difficulty with bathing (Naik & Gill, 2005). The reasons for assistive bathing can fall under ten categories; 1. arthritis/joint pain of hands, arms, and shoulders; 2. arthritis/joint pain of hips, knees, or feet; 3. back pain (all causes); balance problems/unsteadiness in feet; 4. fear of falling, fall injuries; 5. stroke, with weakness of an arm/leg; 6. vision problems; 7. fatigue, generalized weakness, poor endurance, shortness of breath; 8. memory problem/confusion; and other reasons or

conditions (Naik et al., 2004). While bathing is an activity that requires both upper and lower extremities, there is a discussion that technological assistance might substitute for at least some personal assistance in coping with disability (Hoenig, Donald, Jr, & Frank, 2003). Assistive technology has been found to be more efficacious in reducing disability than personal assistance for lower-extremity and body transfer tasks (Verbrugge, Rennert, & Madans, 2007). Additionally it has been observed that the need for assistive technology maybe be viewed as a lesser form of dependence than a need for human assistance, in that the former increased the autonomy of adults with disabilities and facilitates chronic condition of self-management (Allen, Foster, & Berg, 2001). On the other hand, bathing aids have well documented problems (Aminzadeha, 2000; Naik et al., 2004; Steel & Gray, 2009), and show variability in users preferences for bathing aids and usability issues (Ahluwalia et al., 2010).

Problems with bathing

There are many studies that have documented older adults having difficulty bathing (Ahluwalia et al., 2010; Aminzadeha, 2000; Burton, Reed, & Chamberlain, 2011; Cohen-Mansfield & Parpura-Gill, 2007; T M Gill et al., 1998; Thomas M Gill, Allore, Han, & Al, 2006; Thomas M. Gill, Han, & Allore, 2007; Gooptu & Mulley, 1994; Hepherd, 2011; Iliffe, Haines, Gallivan, Booroff, & Goldenberg, 1991; Murphy, Gretebeck, & Alexander, 2007; Murphy, Nyquist, Strasburg, & Alexander, 2006; Naik et al., 2004; Naik & Gill, 2005; Rader et al., 2006; Sveistrup, Lockett, Edwards, & Aminzadeh, 2006). In addition, nine separate studies conducted in-home visits on the interventions of bathing in older adults, as documented by Murphy et al, (2007). Several of these studies attributed the difficulties in

bathing to bending, reaching, stamina/fatigue, and ingress/ egress (Aminzadeha, 2000; Burton et al., 2011; Thomas M. Gill et al., 2007; Kira, 1976; Sveistrup et al., 2006).

Understanding ingress and egress

Specific problems of ingress and egress include getting into or out of the tub and sitting into or getting up from the bottom of the tub. Actions needed for these movements include lifting/lowering, side-to-side/hand-to-hand movements, and standing. Methods of ingress consist of three sub-steps; stepping over the rim with body held erect; bending forward and supporting the body by holding on to the rim and lifting the legs over in front; and sitting on the rim and lifting the legs over in front. The second step is to lower one's body into the tub, the sub-steps are as follows; lowering the body from a standing (or sitting) to a squat position (using body's own restraint mechanism). Then shifting each (weight-bearing) leg into an outreached position and lowering that side of the buttocks onto the tub bottom while simultaneously shifting much of the body weight to it. Egress is performing these steps of ingress in reverse. Egress requires shifting the weight of the body from the buttocks onto the feet, which must become positioned underneath the major weight of the body, then pulling or pushing the body into an upright position (Kira, 1976). Bath sides are too high and deep for those who are smaller, have reduced joint movement or poor strength (Gooptu & Mulley, 1994). Similarly, showers with high steps cause access problems with entry and there are even more issues in getting out (Burton et al., 2011). If users get stuck in the tub they do not try to bathe again, due to further complications such as pressure sores and hypothermia which can be fatal (Gooptu & Mulley, 1994).

Conclusion

Based on the literature, it is found that older adults have difficulty in bathing and that specifically bending, reaching, stamina/fatigue, and ingress/egress are the main issues. I hypothesize that the following changes would improve bathing experience: 1. The rim of the tub was eliminated, could be moved, or if the height was reduced, 2. Supports are added to aid ingress/egress and bending, 3. Objects needed to cleanse (e.g., faucet, drain control, etc.) were closer to the body to reduce reach and stamina/fatigue. While bathing aids have been found to increase user's ability to bathe, there is complexity in trying to fit the different type of aids to a variety of needs. Therefore, a tub that anticipates these multitudes of issues could provide a better bathing experience.

An Examination of Prior Art

The intent of this prior art is to examine the current state of bathtubs and bathtub apparatuses that accommodate people with difficulty entering or exiting the bathtub. These tubs and apparatuses provide more access for users, despite their physical limitations. This paper will examine both patents and product offerings such as walk in tubs, ramps, in tub seats/lifts, and walk-in tubs. Search terms used include bathtub, bathtub for older adults, walk-in bathtub, accessible bathtub, transfer bench, bath lift, and innovative bathtub. These sources were found in the Google patent database and the World Intellectual Property Organization database.

Walk-In Tubs

Transferring into a tub includes ingress into the tub and a stand-to-sit motion, and then after bathing, the user will perform these actions in reverse. Normally, ingressing and egressing

into a tub is achieved by stepping over a 9-12" inch x1-5" inch ledge (Kira, 1976). A common solution to the problem of needing to lift one's legs over a high ledge has been met with variations of a walk-in tub. Here, a walk-in tub will be defined as a tub with a door that opens laterally and has integrated seating with walls on its three sides. Walk-in tubs have a considerably shorter curb to step over, but enough of a ledge to allow for bathing.

Unfortunately, while walk-in tubs are created to improve ingress and egress, they inadvertently create additional problems. The first issue created by traditional walk-in tubs is filling and drainage time. Once the user walks into the tub and closes the door, the user is required to sit in the tub and wait for the water to fill. After bathing, the user is then required to wait for the water to drain before opening the door, standing, and walking out. This is more waiting time than a traditional tub, since users can usually step in and out before waiting for the tub to fill or drain. The second issue created is the possibility of water leakage when the door is closed, and overflow of water when the door is opened. As a result, many walk-in bathtub patents address these specific issues. The earliest walk-in tub patent found was in 1902, Patent 746390 (Schmidt, 1903) has a reservoir within the shell of the tub to allow for quicker drainage, while Patent 2456275 (L. Harris, 1948) and Patent 3663971 (Bonhote, 1972) focus on preventing overflowing water when after door is closed. The first patent has a mechanism feature in which the drain valve can only be closed when the door is closed and the door handle is locked. The latter patent has a drain stopper attached to the door so that it cannot be put into the drain position unless the door is closed, therefore preventing water flooding from the tub. Another issue that occurs with walk-in tubs is ensuring a tight seal. Patent 3863275 (Brendgord & Copeland, 1975) uses a hand pump to

inflate the seal, as does the product Kohler Elevance Rising Wall; a design Patent 613835 (Hoh, Stanchak, Reid, & Clover, 2010) that includes an additional backup seal. Patents 7299509 (Neidich, 2007), 4672693 (Schenstrom, 1987), 4542545 (Johnson & Johnson, 1985), and 3662971(Bonhote, 1972) all have inward doors, citing hydrostatic forces of water helping to create a water tight seal. Notably, Patent 4542545 (Johnson & Johnson, 1985) uses a ferromagnetic faced door stop and magnetic gaskets. Walk-in tubs are an attempt to ease ingress and egress, but fail to allow ingress and egress for those who are non-ambulatory because of the slight ledge. AIA Ultimate (Secure Comfort Bathing, 2014) walk in tub has a fairly low ledge compared to other walk-in-tubs on the market, but that ledge still has about a 3" inch – 4" height, that would still require a person to lift their legs and prohibit non-ambulatory uses from entering. There is a gap in the market for tubs without curbs or a tub that does not have such constraints. In addition, the previously mentioned Elevance Rising Wall that is on the market, has an elevated height that minimizes how much users have to lower themselves and allows for seated transfers. However, there has been a report of a user being trapped inside the tub when the door seal failed to deflate (Houzz, 2014). Another person must be present and physical fit to lower themself under the tub, pull out a panel and pull the plug. Since the product should be one where the product allows the user to be independent, powered products should probably have a backup system.

Shower Ramps

Shower ramps also attempt to ease ingress or egress into a bathtub or shower space and include non-ambulatory users. The following patents all have a ramp that allows users to have a barrier free shower: Patent 20130167347 (Gardner, 2013) is a retrofit ramp that mates

onto an existing bathtub or shower tray, while Patents 5463780 (Harris & McAllister, 1995) and 5341524 (Zellner, 1994) are ramps that can be pivot to a closed vertical position and have a dam or a shower guard that prevents water from splashing out. It is important to note that these patents are designed for shower taking and not for bath taking, as the product are not designed to hold 30-60 gallons of water and water pressure. Although this product allows for a barrier-free ingress and egress that requires no lifting of the leg and allows for shower transport chairs, it fails to allow users to take a bath in it. Whereas both showers and tub baths both provide hygiene functionalities, the tub can provide soothing and calming relaxations that showers do not provide (Kira, 1976).

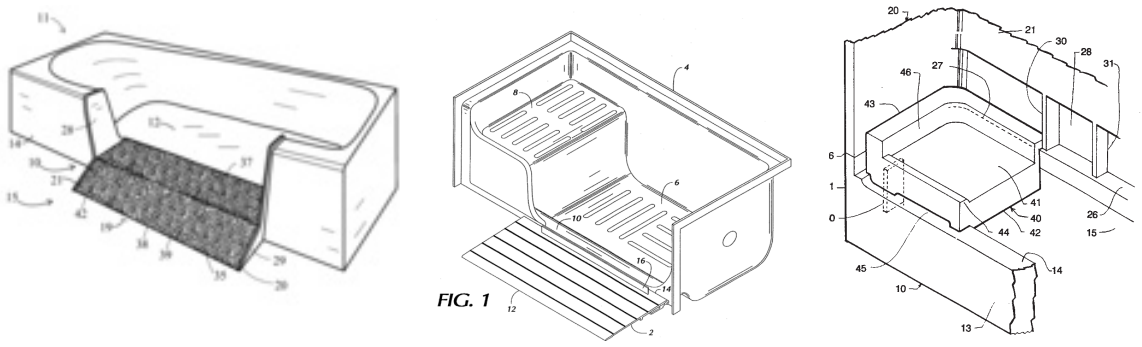


Figure 1. Ramps
(from left to right: Gardner, 2014; Harris & McAllister, 1995; Zellner, 1994)

Bathtub Inserts and Rising/Folding Wall Tubs

Patent 7506385 (Werschmidt, 2009) adds the capability for the user to submerge into the bathtub. This patent has a commode seating with adjustable back and leg support. The chair assembly can traverse along a glide track between the extended seat assembly and the submerging bench assembly can assist with ingress and egress. While ingress/egress is the main problem in taking a bath, it is important to identify that being able to bathe or submerge

into water is also important and can often be a step that is integrated into the ingress/egress process in products. These next set of patents and products address the issue of stepping over a high curb and the issue of submerging into water with the stand-to-sit/sit-to-stand motion: Patent 3719960 (Russel, 1973) is a traditional walk-in tub, except that, as opposed to the other walk-in-tub patents listed, when the door opens, the tub seat is exposed to give the user the option of sliding in or stepping in. The following patents and products completely eliminate the need or option to enter and exiting the tub by standing. Patent 20100275364 (Torres & Slepicka, 2010) consists of a rising wall where the user slides into, and addresses drainage problems by including a gray water reservoir under the tub for a high capacity tub drain. The product Vanna Height Adjustable Bath consists of a wall that is folded out into a lateral extension when open and is also unique in that it is height adjustable (Astor Bannerman, 2013).

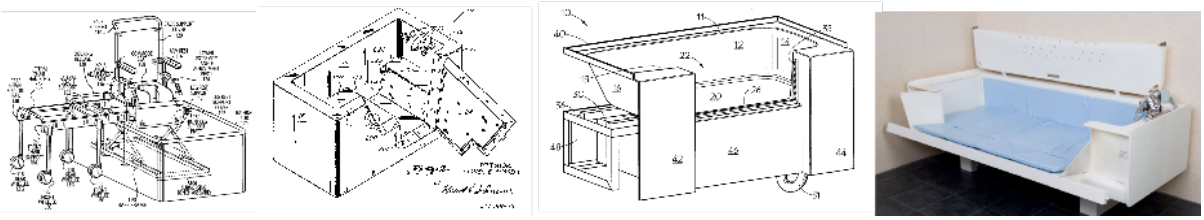


Figure 2. Bathtub Inserts and Rising/Folding Wall Tubs
(from left to right: Werschmidt, 2009; Russel, 1973; Torres & Slepicka, 2010; Astor Bannerman, 2013)

Patent 5036555 (Oudt, 1991) is a complete bathing unit with a platform that raises up and down. Inside there is a vertically adjustable bottom portion and fluid receiving channels, with springs and a tension adjuster. Patent 5678256 attempts to allow a user to submerge one's self into the tub with three steps inside the tub so that a person could lower and maneuver

their buttocks one step at a time into the bathtub (Lea, 1997). The likelihood of leaks is non-existent (Walker, 1976). However, comfort while bathing and the strength needed to physically move one's body up and down these stairs are both concerns.

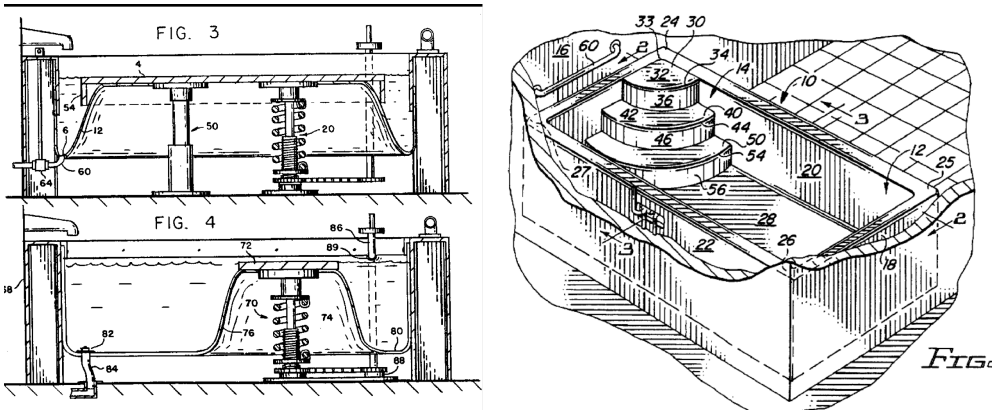


Figure 3. Platforms (left: Oudt, 1991; right: Lea, 1997)

Cushion Lifts

Bathtub cushion lifts are often lightweight, with forms varying between a u-shape and a block shape. Patent 4534074 (Herman, 1985) is a shell that inflates with water. The shell consists of horizontal tubes forming an elliptical cross-section that contribute to the tapered shape for added stability. Patent 5855028 (Colbert, 1999) has a similar form but uses an air pump. Patent 6336230 (Lane, 2002) and is formed with three separate sections for a more stable form, and is secured to the tub using a suction cup. The general issues with bath lifts lie in the difficulty of anchoring down a bath lift so it does not float, making a bath lift comfortable when deflated, and deflating uniformly so that a person does not tip forward, backward, or to either side (Colbert, 1999).

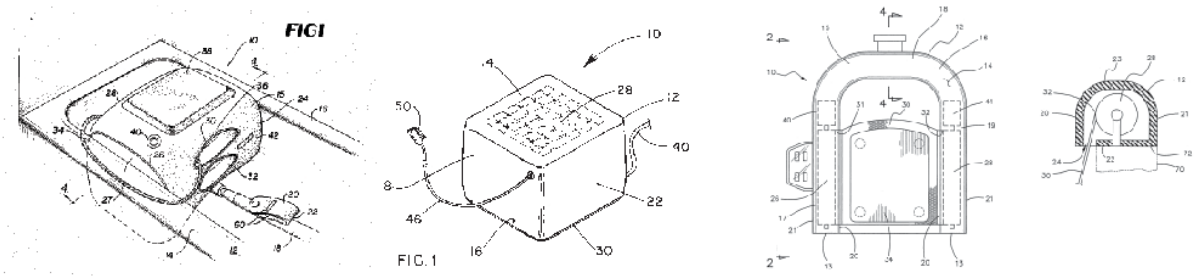


Figure 4. Cushion Lifts
(from left to right: Herman, 1985; Colbert, 1999; Lane, 2002)

Tub lifts automate this uniform motion, and similar products assist in ingress and egress into the tub, including submerging into the tub. Patent 5924147 (Clarke & Mettler, 1992) makes use of an existing bathtub as support. Using worm-gear and hydraulics, a bathing seat is created that revolves from outside the tub to the inside, and then lowers inside. It takes minimal space, because the body is wrapped around the tub. Alton Bathtub Lift (source) is an electric lift that has the same function, but lifts from above instead of below. Unfortunately, Iowa Veterans Home physician, T. Cheuk has noted that these types of lifts have been said to be uncomfortable and can pinch the skin (personal communication), Oct 10, 2014). Patent 6199226 (Steadman, 2007) also aims to lower and raise a person using a motor from a seated position to the bottom of the bathtub, while also providing sufficient support and security using motors with gears connecting to rollers. The patent claims that this is a more stable transfer option. This object can be folded upwards onto the wall for storage. ShowerBuddy (http://tadpoleadaptive.com/showerbuddy-tubdipper.html) only assists with lowering. This product is particularly interesting because it rises and lowers mechanically.

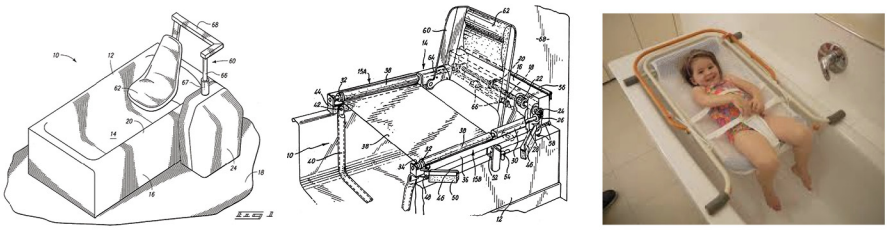


Figure 5. Tub Lifts (from left to right: Clarke & Mettler, 1992; Steadman, 2007; ShowerBuddy)

In summary, no one product fully enables users to transfer in sitting, to walk in, to roll in, and allows for bathing. Overall, walk-in tubs allow for easier ingress, egress, and stand-to-sit-motion, but maintains a curb that excludes wheelchair users and other users with, for example, poor balance or poor sight. Shower ramps assist with the ingress and egress of a tub by essentially building a ramp into an existing tub to allow users to easily enter. However, these ramps do not allow for bath taking. Transfer benches allow users to access the tub, but do not let them submerge fully into the tub, making it difficult to achieve full bathing experiences. Hybrid walk-in tubs, tub lifts, and air cushions combine the ideas of transfer benches and integrated seats from a walk-in tub. Some of these hybrids are designed to lower a user into the tub, or have the tub at an elevated level and eliminates the need to lower the user, but excludes users who need to roll in to the tub using a shower wheelchair. Ultimately, the prior art reveals that there is opportunity for development of an improved bathtub that allows users with various needs to ingress/egress.

Observation of Existing Videos

My intent in this observation phase was to find out how individuals transferred and to learn the nuances of the bathtub transfer process, particularly how those with limited mobility transfer into and out of a tub. This observation process and the results of analysis helped build the design criteria.

Observation Method

60 tub and shower transfer videos were watched. The videos were collected from YouTube and videos from a previous study at the Center for Assistive Technology and Environmental Access. The videos consisted of two main groups: young to middle age users with limited mobility demonstrating for others how they get into the tub while giving advice on how to make transfer easier, and an older adult group with limited mobility that was videotaped by researchers that did minimal guiding. Of these 60 videos, 20 videos that met the criteria of depicting tub transfers with clear video quality showing the whole process were chosen. Video analysis was chosen over doing in-home observations because there is already an abundant source of shower and tub transfer videos that exist online and more importantly because these videos show one point in time. This means that analyzing these videos from the online source would serve the same purpose as in-home observation and analysis. The analyzing of the videos produced three types of findings.

Findings I

The first was collecting user comments, and placing them into an online visualizer called “Wordle" that captures instances of word use. The bigger the word size generated

proportionally indicates the number of times the word was used in the original data set. It was learned that the subjects analyzed approach bathing in a very methodical way, breaking up each process into specific physical steps that they pay attention to. In the videos, there is a lot of mention of using towels to soften the hard tub when sitting, the learning process they go through while bathing, and how there is an underlying fear of slipping. When traveling, many users modify hotel objects to assist with transferring and grab onto unstable objects such as doors and faucets. In figure 6, you can see the "Wordle" is filled with specific action steps to help them transfer safely.

Figure 6. Wordle, Capturing User's Bathing Methods and Concerns

Findings II

The second sent of findings from analyzing the videos was done by gathering themes of transfer styles and categorizing each user under the themes. It was realized that that users transfer in and out using the same method. As a previous grab bar study has found (Guitard, Sveistrup, Edwards, & Lockett, 2011)**,** users make use of the tub rim often. It was observed that a lot of the wheelchair users transfer at an angle to allow for easier rotation. There were instances when users were not able to lower themselves into the bathtub at the time they were being taped due to fear, physical exhaustion, and shakiness of their upper body. Those who used an inside bar tended to have good upper body strength, but also seemed to lower their body into the tub with better confidence than those who did not have a bar integrated into the inner tub rim wall.

Table 1. Categorizing Observations to Find Bathing Behavior Patterns

Observations	**Subjects**
Physical conditions change quickly (meaning support needs also changed quickly)	2,
Those that use tub benches do not use the bath rim. The rim can become a barrier for legs.	1, 2, 10
A trouble seems to be reach (reaching to turn on the water - support needed)	2, 7
Support object is pushed away so the body can rotate easily into vessel	2, 7
Transferring in and out similar body positioning and touch points.	1, 2, 6, 7, 8, 10, 11
Transfer to toilet to towel off	2, 3
Makes use of vanity to help with lowering	3

Table #1 continued

Makes use of vanity to help with rising	2
Makes use of vanity to step over barrier	4
Mentioned bathing as very risky/ dangerous - improper supports/ or not using supports when they are needed	2
Unsteady when lowering oneself into the tub of weight on arms (unsteady) + no use of supports to lower	3, 4, 8
Uses towels/pad to sit on tub bath	4, 7
Turns over to transfer out (different way of entering from exiting tub)	4
Used the vanity as a support	2, 3, 4
Used the toilet as a support	2, 3,
Sits on tub rim to transfer	7, 8, 9, 10
Tub rim was a barrier in transferring	1, 2, 4, 5
Lowers down from tub rear	4
Turns over to push up (versus pushing off from back)	4
Shower bench bath	1, 2, 5, 6
Bath without a shower bench	3, 4
Grab Bar Rail(clamp on grab bar)	7, 12,
Towels on tub rim (to sit or transfer leg on)	5, 8
Anytime a person sits on one side first and then transfers legs, the legs will hit the other side of tub; Foot often hits tub (outside and top) because you need to bring it into your body over a barrier vs. away from your body over a barrier (hits top)	2, 8, 10
Almost slips	1
People tend to turn their wheelchairs at an angle due to wheelchair wheel obstruction/easier body movement	11
Grab bars on inside tub help with lowering	11, 8

Findings III

The third set of findings from analyzing the videos are touch points. To find these touch points, I need to identify the variables and attach a code to each variable. There were a high number of variables with movements and patterns that were initially looked at. After looking at adopting variables from other studies, it occurred to me that it is not important to identify these individual's limited mobility or psychological emotions but rather focus solely on different types of transfer patterns. I wanted to understand how users move and behave. To do this I divided the subjects in four groups: 1) subjects that do not use assistive technology, 2) subjects that use grab bars, 3) subjects that use tub benches, and 4) subjects that use both assistive technologies. I hypothesize these behaviors and patterns could help me determine the form of the tub that is needed. To understand the patterns, first a coding system was devised; second, the codes were then put into a chart in order to visualize the patterns. At first, there were a total of 14 variables that were looked at. These variables were broken up into three sections for the sake of clarity. The first section of observations coded included understanding the environment of the user: the tasks, limitations, age ranges, and vessel orientation:

Table 2. Section 1 of 3, Codes for Observations

task		limitations		age		vessel
bath	L1	Mobility	A1	child	V1	right drain tub
shower	L2	Vision	A2	young adult 18-35	V2	left drain tub
		Hearing	A3	middle adult 36-55	V3	right drain shower
				older adult 55+	V4	left drain shower

The second section of variables included looking at what actions the users were doing, at what posture, and in what direction.

Table 3. Section 2 of 3, Codes for Environment

category		posture		direction
Positioning	P1	Elevated Sitting	D1	Facing Vessel
Into Vessel	P2	Floor Sitting	D2	Back to Vessel
Lowering	P3	Standing	D3	Parallel to Vessel (facing drain)
Rising			D4	Parallel Slight Angle Vessel (facing drain)
Out of vessel			D5	Parallel to Vessel (back to drain)
Turning Water On			D6	Parallel Slight Angle Vessel (back to drain)
Lifting Legs				

The third and last section of variables directly related to the second section of variables and included what body parts were at which touch points (e.g., top view and side view). The tub was split into nine sections, to accommodate for bigger touch points (e.g., subject's butt) and divided into 12 sections for smaller touch points (e.g., hands, feet, elbows). Height was roughly estimated into six sections. The heights were estimated in a way in which things were relative to one another.

Table 4. Section 3 of 3, Codes for Body Parts and Objects

	Body part		Object
B1	rear (butt)	O1	wheelchair
B2	hands	O2	walker
B3	hand left	O3	wall
B4	hand right	O4	tub rim top 1-2"
B5	head	O5	tub rim top 2-4"
B6	elbows	O6	tub rim top 4"+
B7	left elbow	O7	tub rim inner
B8	elbow right	O8	tub middle
B9	feet	O9	tub bottom
B10	foot left	O10	towel/cushion + tub bottom
B11	foot right	O11	grab bar integrated in tub
B12	legs	O12	tub bench
B13	leg left	O13	tub integrated seating 10"
B14	leg right	O14	grab bar - horizontal, 8-12"
B15	chest	O15	grab bar - horizontal, 18-36"
		O16	grab bar - horizontal, 42-54"
		O17	grab bar - vertical
		O18	clamp on grab bar

Table #4 continued

		O19	toilet
		O20	vanity
		O21	towel bar
		O22	soap dish
		O23	door
		O24	door knob
		O25	faucet
		O26	hotel/household objects
		O27	hotel/household objects on toilet

Top View

A11	B11	C11
A10	B10	C10
A2	B2	C2
A3	B3	C3

side view

D5 (S-D5, 51"+)
D4 (S-D4, 48" (50")
D3 S-D3, 33-36" (40")
D2 S-D2, 25-29" (30"
D1 S-D1, (25")
D0 S-D0, 17-19" (20")
D-2

Figure 7. Section 3 of 3, Codes for Location: 12 Sections for Smaller Touch Points; 6 Sections for Side View

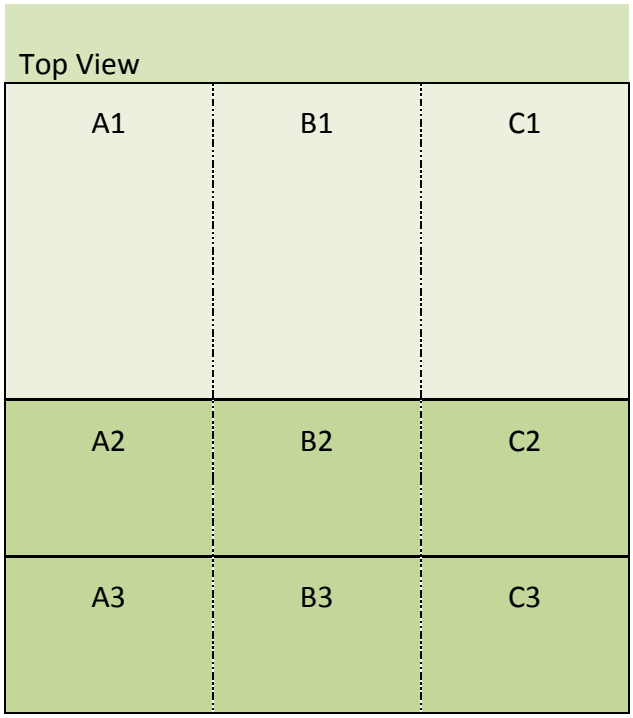


Figure 8. Section 3 of 3, Codes for Location: 9 Sections for Bigger Touch Points

Re-organizing and condensing the coding criteria was critical to be able to gather data consistently and quickly without over simplifying the data. It was learned that most subjects transfer into the tub the same way they transfer out. Therefore, the final variables were parsed out to 1. Start position, 2. Transferring touch points, and 3. Ending location in tub. Initially, the touch point objects included a very long list, but to improve efficiency in evaluating data the touch point objects were narrowed down to the essentials: wheelchair, tub bench, toilet, vanity, grab bar, and dish/toilet paper holder/towel bar. The subjects were divided into different categories to find themes. In order to see the data clearly, butt touch points and hand touch points were looked at separately. The butt touch points and hand touch points were both separated into four categories: 8 subjects with no assistive tech, 6 subjects

with grab bars, 3 subjects with tub bench, and 3 subjects with both grab bars and tub bench. 14 of the subjects were wheelchair users, 1 subject used a walker. 3 subjects were amputees.

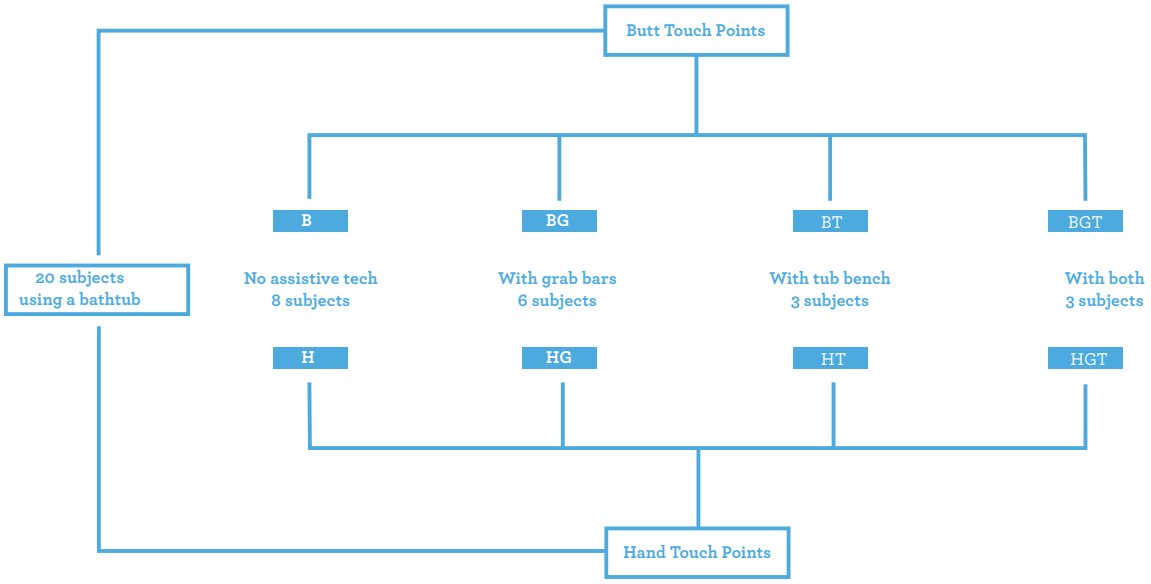


Figure 9. Dividing Subjects into Categories

After the touch points were coded, the data was plugged into the online visualization tool "Plotly", and then edited in Adobe Illustrator. In "Plotly", I defined the variables and plugged in x and y coordinates of each touch point to create a 2d graph. For 3d graphs I plugged in x, y and z coordinates. Then, I used Adobe Illustrator to polish the visual look of the graphs. A top view was chosen to understand the transfer patterns and a 3-D bubble chart was chosen to understand the touch points in the context of the full bathroom space. In the graphs, the bathroom space has been divided into quadrants of space. On the x axis, the bathroom has been divided into four quadrants and on the y axis the quadrant has been divided into three quadrants. These quadrants were devised based on looking at the bathroom space. Although not all bathrooms were the same size, most of the bathrooms used a regular tub, and I used

the bathtub as a way to proportionally estimate the bathroom space. Each color represents a subject's touch point in the space. Items such as a vanity, toilet, or wheelchair were only included if the subject used that item.

Insights from Observations

Some graphs yielded more information than other graphs. The graph "Error Touch Points/Barriers" (figure 10) provided insight into specific barrier locations for user's leg and assistive technology. Looking at the graph (figure 10), it was learned that quadrant 0-1 (y axis), the tub rim height of 15"-20" is a barrier. Quadrant 1-2 (y axis), the tub rim height of 15"-10" is a barrier for legs. Quadrant 2-3 (y axis), the rim was not a barrier for users. These error touch points were predominately from users who transferred from a seated position to a seated position (e.g. from toilet/wheelchair to tub rim/tub bench). This helps outline the necessary space requirements for a seated transfer to eliminate barriers for the legs.

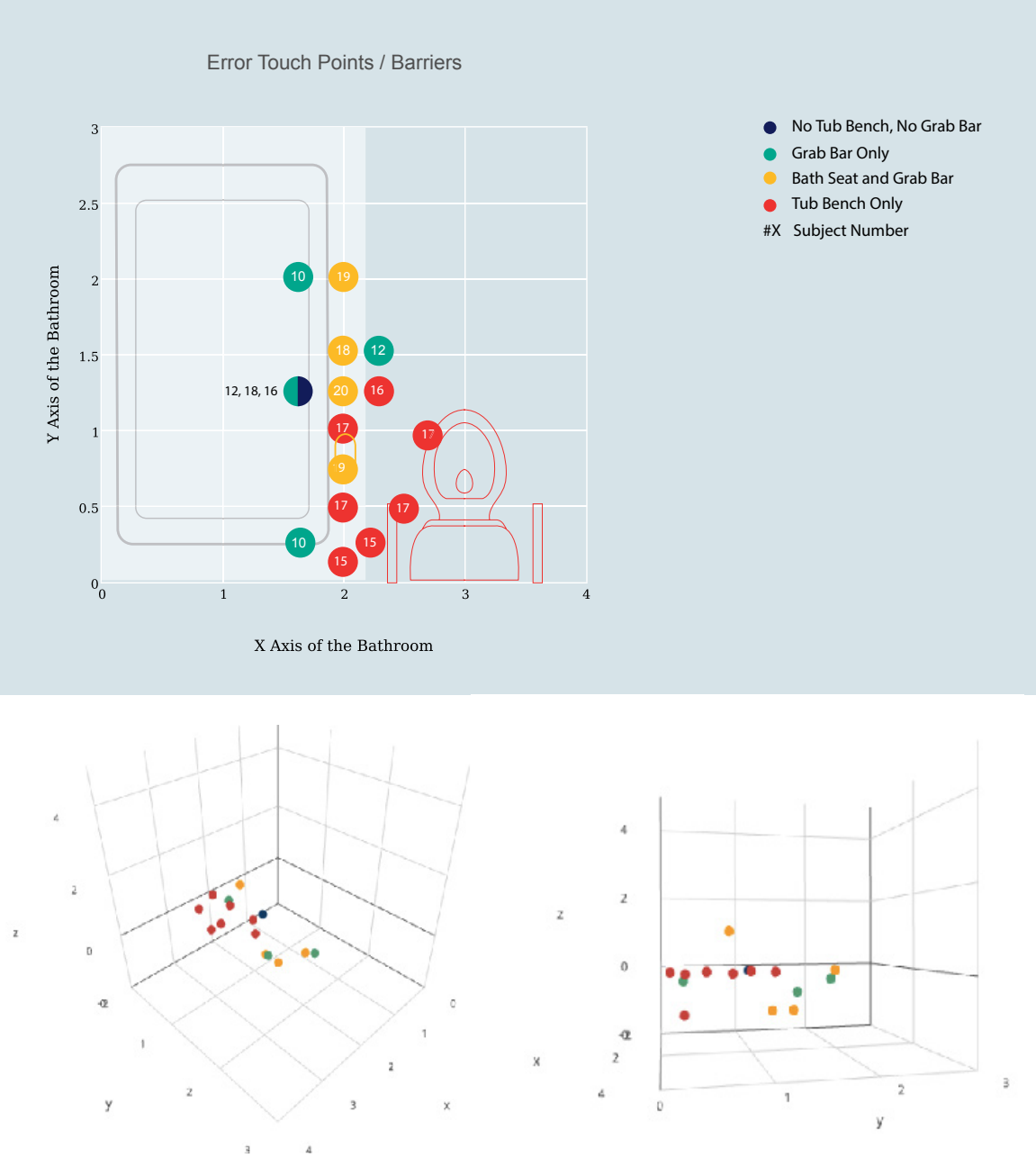


Figure 10. Error Touch Points / Barriers

Insight from Hand Touch Points, With Grab Bars and Tub Bench (HGT): I was able to obtain the most insight from chart this graph (figure 11) as there are extra movements and actions required. Clamp on rails assist upper body transfer from wheelchair to tub rim. Tub rails obstruct body from rim to tub. For the two users who used tub rails, they were placed in the

exact location, about ¼ into the tub from the faucet (2, 1.75). This insight is important because it reveals that this height is very useful in standing up and lowering in supporting the body, that the stepped height in the bar is used, but also that when legs must be transferred – it becomes a barrier. This observation can lead to a re-design in tub rails for those looking for minimal support. For tub bench users, grab bars placed at the faucet (front) are used for upper body stability to pull legs over. For tub bench users, side grab bars are used to pull themselves in and for stability while pulling other body parts in and used for support to clean their body parts. This insight could be important for elevated bathtubs, as the body needs front support if legs need to be lifted. The implication could be that grab bars might not be needed or fewer grab bars would be needed if barriers for legs are removed. When doing seated transfers from wheelchairs to the tub, most users chose to transfer with their wheelchairs at an angle and then pivot their butt into the tub. The reasons are that there are fewer barriers from wheelchair wheels, the movement can be conducted in one motion, and the user's legs can be positioned closer to the tub. Faucets that come out in the center of the tub are awkward for the subject's bodies to move around.

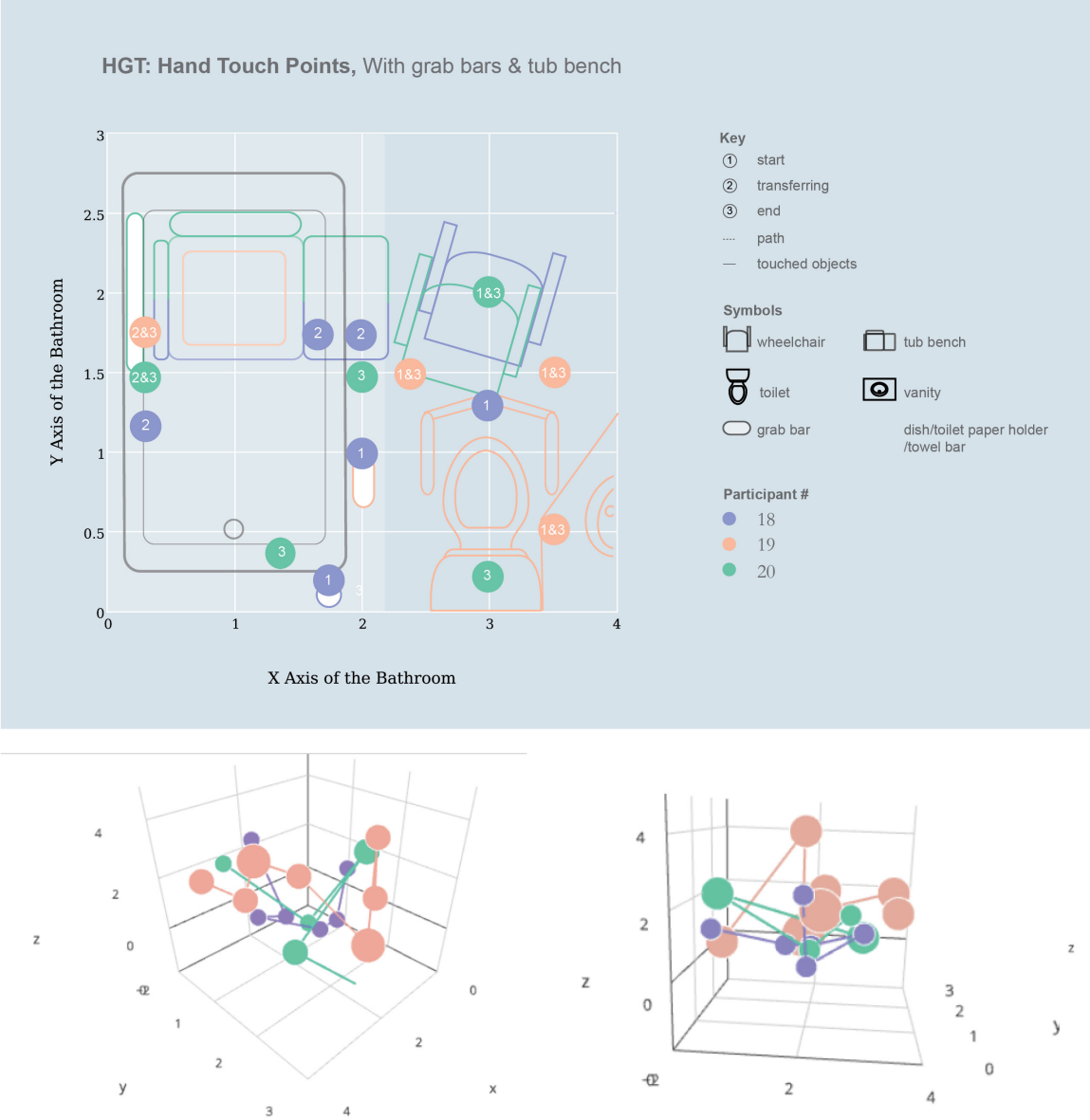


Figure 11. Hand Touch Points, With Grab Bars & Tub Bench (HGT)

Insight from Hand Touch Points, with Tub Bench (HT):

Hands tend to reach out for support on either side of body;

it seems that users would benefit from support in front of their body.

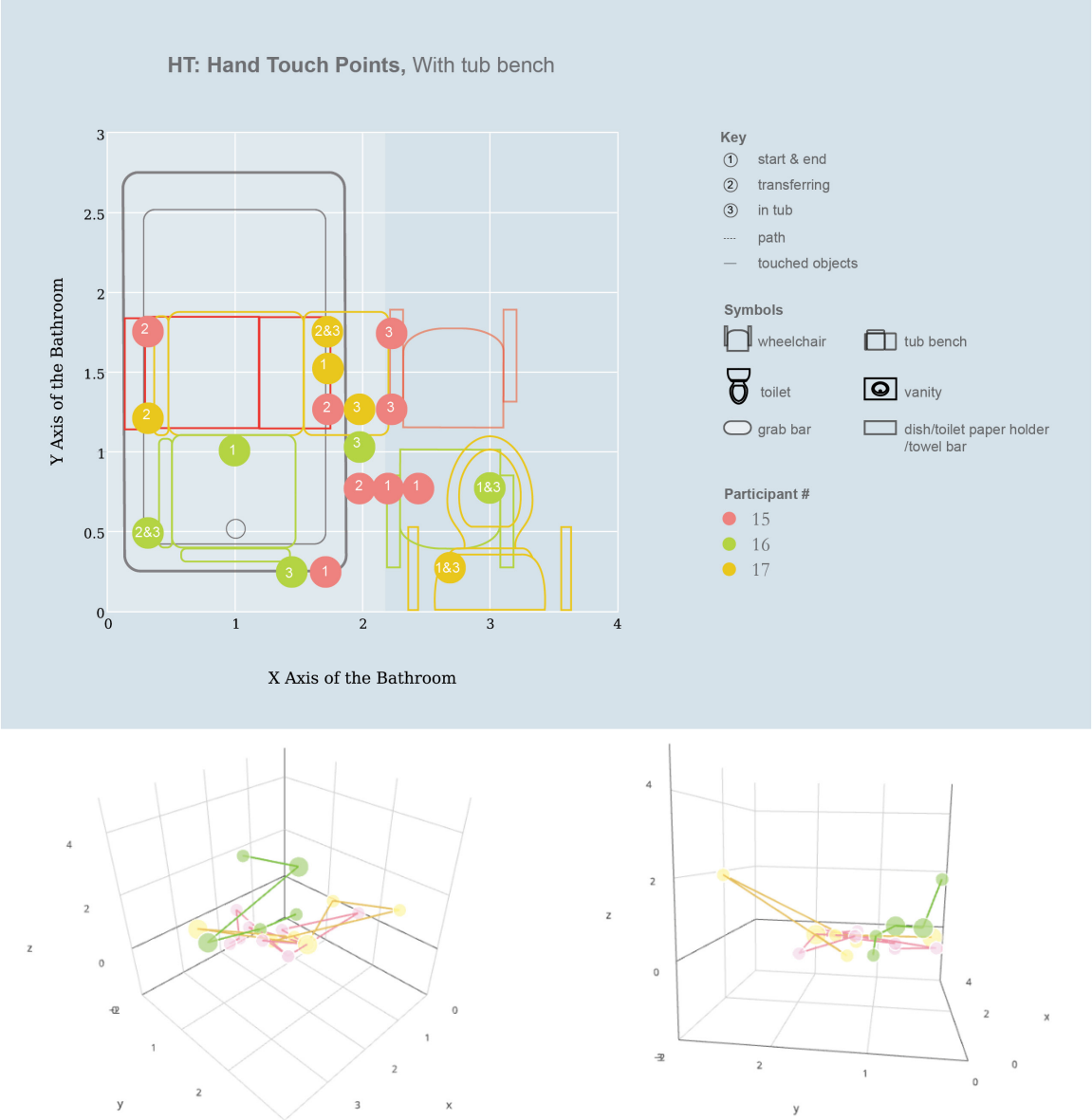


Figure 12. Hand Touch Points, With Tub Bench (HT)

Insight from Hand Touch Points, with No Assistive Technology (H):

Because of how the rectangular tub is formed, and how a body is situated at the opposing end of the faucet to make rooms for legs to extend, a person's body is far from the faucet and hands do not reach the inner right corner of the drain. In addition, there is no grab bar (which would be placed in a higher position than the user is currently touching) so there is no reason

to voluntarily reach for that area. Due to the anatomy of the human body when sitting down in the standard tub and the need of support towards the side of the tub that the user is exiting, quadrant (1, 1.5), the inner right corner near the drain is not a place of support for users hands. All eight of the subjects under the category- H, placed their hands along quadrant (.25, 1.5) and (.25- 2.75), from the middle of the tub to the rear most position of the tub along the tub rim. Aside from the tub rim, the two ambulatory users placed their hands on objects other than the tub (i.e., wall, dish soap holder, and door knob) indicating the need of higher support in these specific locations (2,2), (2,4). It was also found that there is a need of multiple supports at a higher location when the subject is rising from sit to stand (near back of tub), and a need of support (2,1) when rising and exiting the tub (near the faucet). The majority of hand touches were along the tub rim- all along the outside, and the right half of the inner back of the tub. Hand touches entering the tub and exiting the tub were often in the same location. When exiting tubs, there were touches along the bottom of the tub to push off. My observations agree with the study (cite study), that users need higher support when exiting the tub. More specifically, there seems to be “hot spots” that users grab when there are no grab bars: (x axis 2 =1/3 of the tub from the right). Below, both hand touch points and butt touch points are shown for the users not using assistive technology.

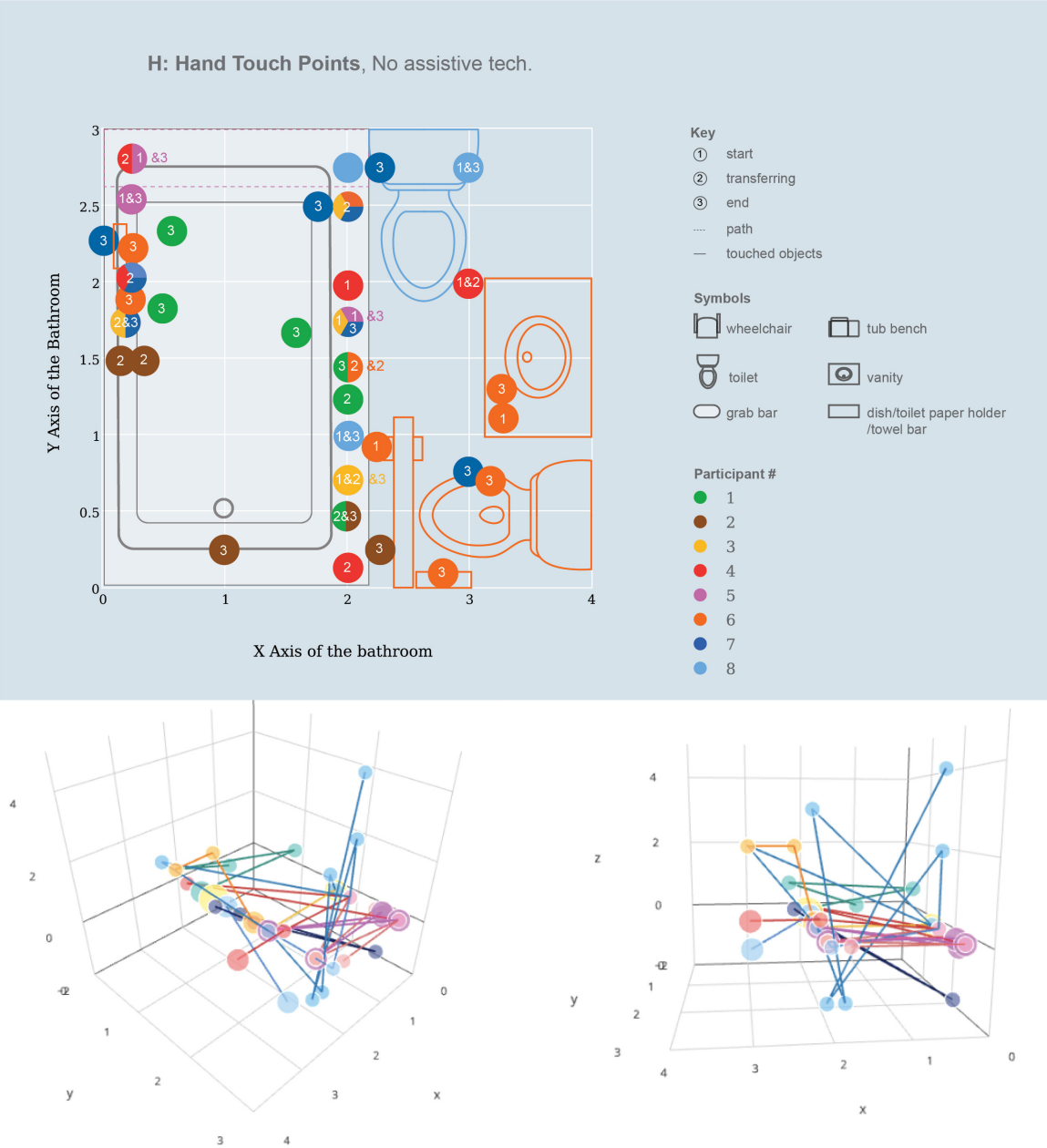


Figure 13. Hand Touch Points, No Assistive Tech (H)

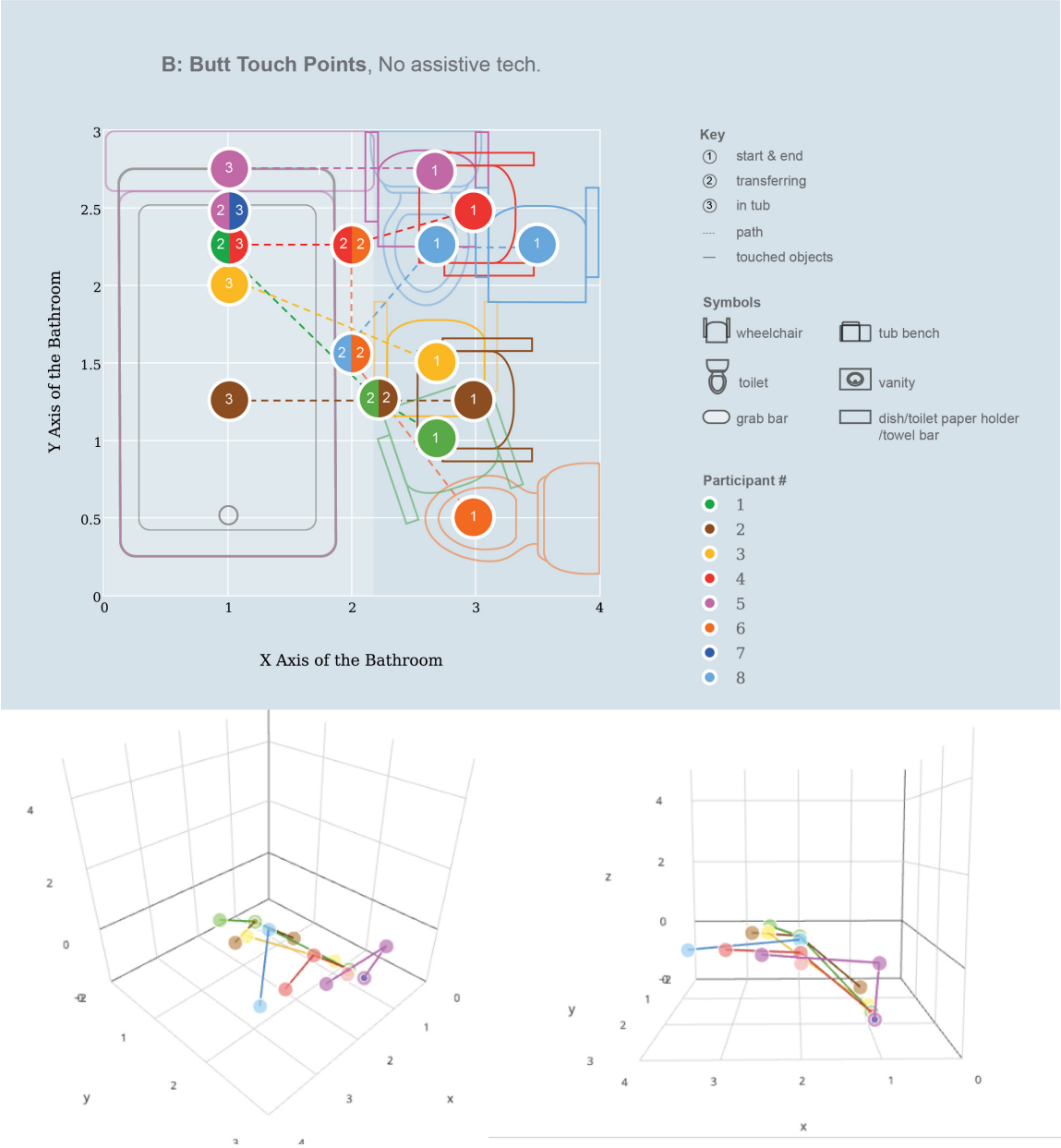


Figure 14. Butt Touch Points, No Assistive Tech (B)

General Insights from the Graphs

When there is no assistive technology used in bathtub transfer, user's hands tend to touch everything. The most left and right inner corners of the tub are almost never touched. The reason being, it's too far from where a person needs to sit, and they exit the tub on the

opposite side. At the end of the bathing process, users who were ambulatory sat on the toilet to rest and towel off. Bathing is a whole process, and does not end until the user is dressed and leaves. Including the end process, while is not necessary, can be an added comfort for the user. When users transfer with grab bars, they move in a slightly predictable pattern and wheelchair users tend to reach higher as they have the option to grab on to something. Tub bench users have the most predictable transfer pattern as they move laterally. They also often used tub bench as support, grabbing on to the edge of the seat, the edge of the seat back, the grab bar attached to the seat, and the inside of the seats with cutouts. Users with grab bars and tub bench tend to move toward the rear as the grab bars allow them to lean forward for the faucet. The rest of the charts are included below. Figure 15 Butt Touch Points with Tub Bench (BT) show that these subjects who transfer from seated position to seated positions predominately transfer from their seat to the tub rim and then to the shower bench. It also shows that the subjects don't necessarily transfer in consistent manners. However, when grab bars are installed (grab bars installed on walls, clamp on grab bars, and integrated grab bars in tubs) it can regulate subjects transfer patterns. This observation can be seen when comparing Figure 16 Butt Touch Points with Grab Bars (BTG), and Figure 17 Butt Touch Points with Grab Bars (BG). Figure 18 Hand Touch Points with Grab Bars (HG) show that many wheelchair users use their own wheelchair as support to push off. The chart also shows that subjects having many touch points near the inside walls where they have installed grab bars and along the rim of the tub, perhaps indicating two different heights of supports needed. There were grab bars installed toward the front of the tub, but because these users are seated on the floor of the tub with their legs laid out in front of them, they were not as useful in aiding the subjects to exit. Most of the touch points seem to collect along the center of the

outer rim of the tub and the center of the inner rim of the tub. This could be a good indicator of where to locate supports.

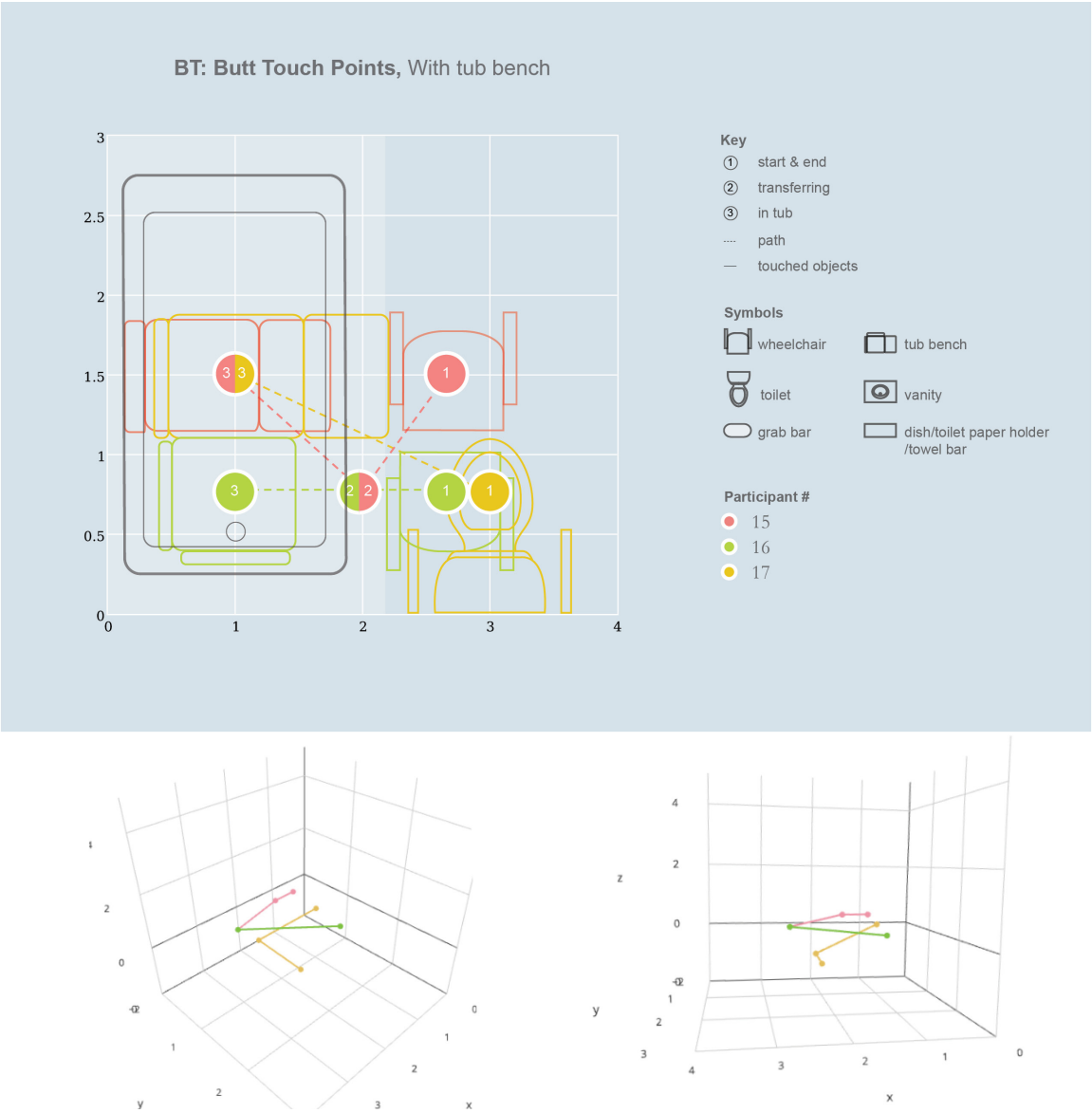


Figure 15. Butt Touch Points, With Tub Bench (BT)

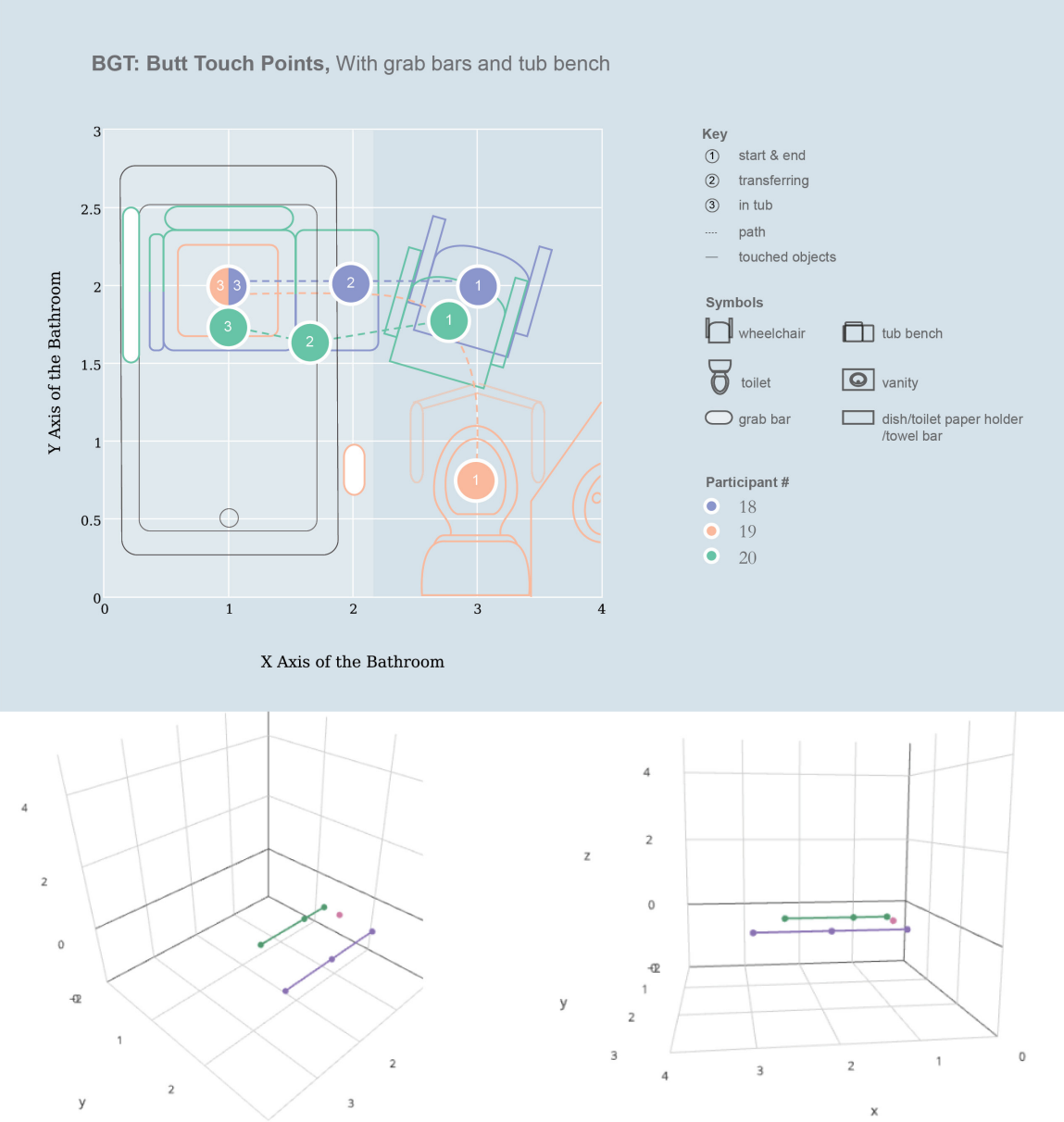


Figure 16. Butt Touch Points, With Tub Bench and Grab Bars (BTG)

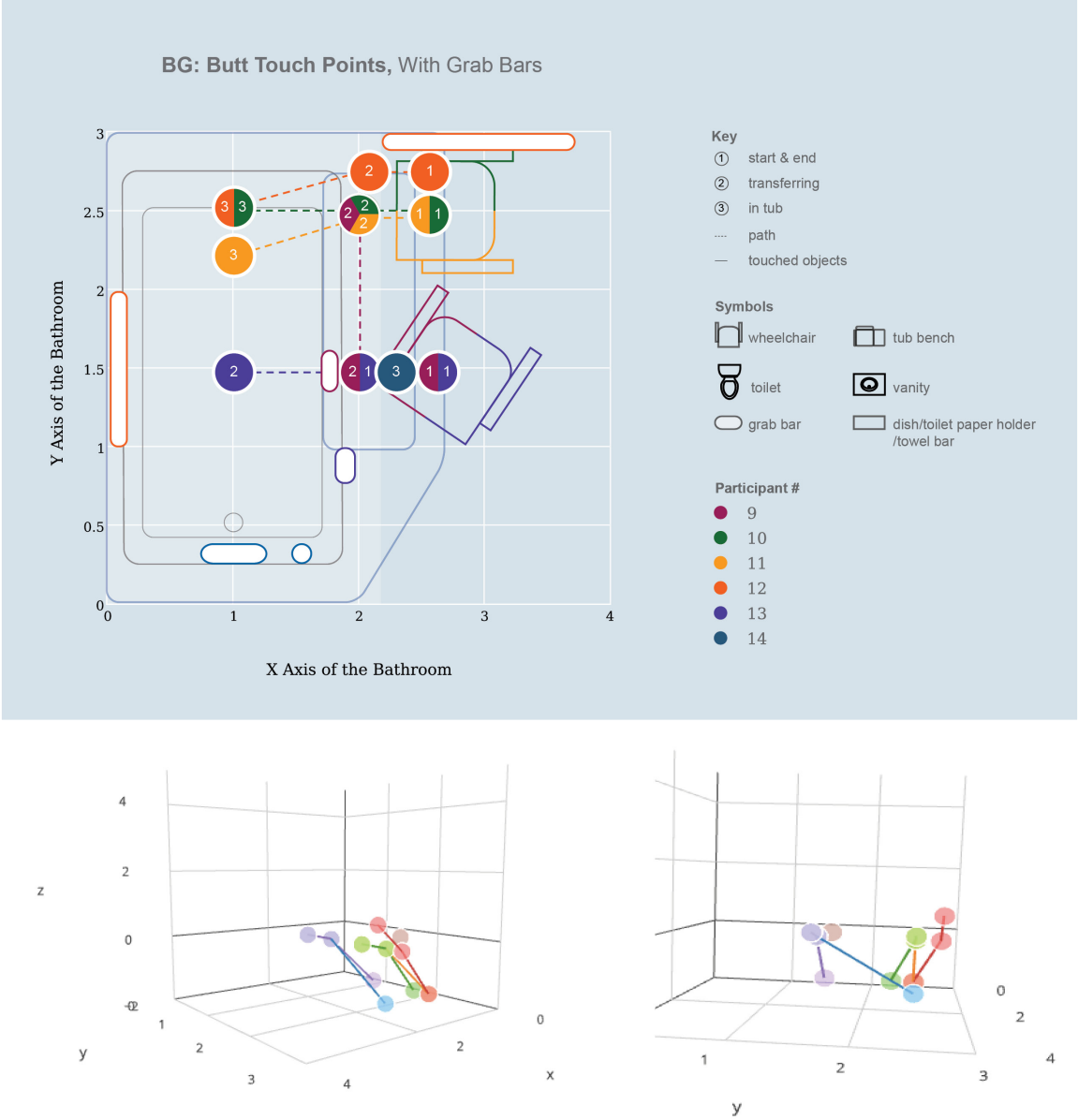


Figure 17. Butt Touch Points, With Grab Bars (BG)

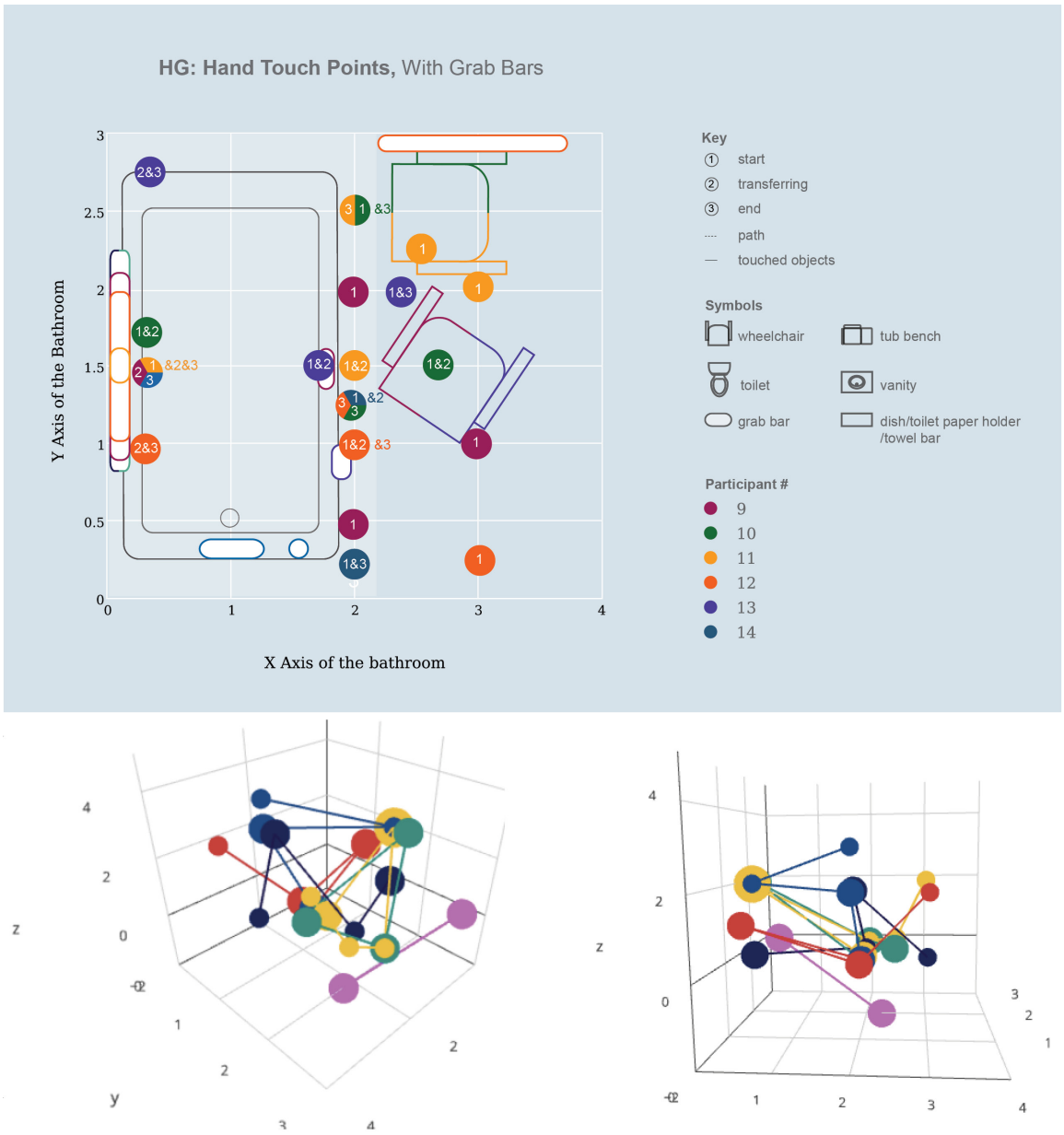


Figure 18. Hand Touch Points with Grab Bars (HG)

CHAPTER 4

CRITERIA

Design Criteria

The following design criteria were developed based on the literature review, the prior art, and the video analysis:

1. Eliminate barriers for legs

a. If users transfer laterally by themselves: the tub rim, quadrant 0-1 located on the y axis should be below 15" inches.

b. The tub rim, quadrant 1-2 located on the y axis should be below 5" inches.

c. The tub rim, quadrant (2, 1.75, 0 to 1) is a barrier for legs

The literature cited ingress and egress as one of the reasons for difficulty in bathing. These specific locations of barriers were gathered from the video analysis of the subject's error touch points.

2. Tub should include support for upper body

a. Front bars if user needs to lift legs to enter/exit

b. If users transfer laterally by themselves

c. To assist with cleaning body parts

d. To lower and raise oneself into water

These observations are gathered from analyzing users hand touch points. The maximum height support would be needed is at 5 feet (CAESAR database, based off of the average height of American men).

3. Should be an integrated fit in the environment, socially and physically

The tub should be usable by a wide range of users regardless of limited mobility and the tub should not impeded users bathing. This decision was made from the observations made when analyzing users with assistive technology.

4. Users must be able to take a bath and a shower

Must hold water (soak: water level is up to belly; bath: water level is up to chest

The literature emphasizes the variability in user's preference towards cleansing method (e.g., bathing, showering, sponge bath) and bathing aid. Therefore, to accommodate for a variety of users, it is best to accommodate for the different type of bathing methods: shower, tub, and sponge (Ahluwalia et al., 2010), however since sponging can be done in the bathroom or room, this study will focus on accommodation for shower and tub usage. The height level of where the water touches defines the difference between a soak and a bath (Miller, 1994). Many comments from an Amazon review of a bath lift show complaints that due to the mechanism that is part of the bath lift, they only able to achieve a soak and not a bath ("Drive Medical Blue Whisper Ulta Quiet Bathtub Lift, Grey: Customer Review," n.d.).

5. Form should coincide with assistive technology (i.e. walker/wheelchair)

a. The form should accommodate for seated transfers, in most cases, wheelchair users.

b. The form should not have parts that jut out or impede users (e.g. walker users, wheelchair users, etc.)

Comments from the observation reveals that the assistive technology is not always a good fit with the tub. For example, one subject uses a book to elevate an adjustable shower bench

because it was too short for his tub. A study (Murphy et al., 2007) has been found that that one of the reasons users stop using bathing devices is that they are awkward and unsafe to use. Other reasons cited were that the users have a denial of need and feelings of embarassment. Another study (Naik & Gill, 2005) has found that older adults who have difficulty bathing underutilize potentially useful environmental adaptations (e.g. grab bars, tub benches, handheld shower sprays). When considering multiper users, these finding goes on to solidify the reason why an envrionment for bathing would be more suitable than an assistive technology.

6. Should fit the U.S. average bathroom size of 5' x 8'

This decision was made to expand the number of users that would buy/use the tub.

Market Analysis Based on the Design Criteria

The Thought Process

The prior art helped in identifying what is already out there, the problems, and previous approaches that tried to solve these problems. In order to evaluate the products in a way that mattered to this study, a market analysis was created that compared the current products with the design criteria. Taking from the general design criteria, specific points were parsed out for the market analysis. From design criteria "#1 Eliminate barriers for legs" the variable: addresses barriers, and assists entering were added. From the design criteria, "#2 Tub should include support for upper body" the variables: includes support, and stability were added. The design criteria, "3. Should be an integrated fit in the environment, socially and physically" was initially omitted because many of these products were made for one purpose

they would not fulfill this design criteria. Accordingly, further investigation would have to be done on this specific matter. For design criteria "#4, Users must be able to take a bath and shower", body bath (to chest), soak (to belly), shower; were listed. For design criteria "5. Form should coincide with assistive technology (i.e. walker/wheelchair), the variable: wheelchair compatible was added. For design criteria "6. Should fit the U.S. average bathroom size of 5' x 8'" were omitted because all the products listed fit in a 5' x 8' bathroom. Two other things I was curious about included whether or not it offered a non-electric option, and the price to understand the product on the market holistically. If this chart was analyzing other types of bathing products with more variability, listing the omitted two design criteria in the market analysis might be useful.

Table 5. Market Analysis based on Design Criteria

Product	Product Name	Category	Full Body Bath (to chest)	Soak (to belly)	Shower	Wheel-chair Com-patible	Address-es Barri-ers	Assists Entering	Includes Support	Stability	Non-Electric Option	Price
		Transfer Seat				✔					✔	**$35- $60**
		Transfer Bench (extended)				✔			✔	✔	✔	**$50- $120**
		Transfer Bench (sliding)				✔		✔		✔	✔	**$135-500**
		Transfer Bench (sliding & turning)				✔	✔	✔		✔	✔	**$120-279**
	Cushion Bath Lift	Bath Lift (cushion)		✔		✔			✔			**$502**
	Drive Medical Blue Whisper	Bath Lift (battery operated)		✔			✔			✔	✔	**$1, 482**
	Portable Bath Lift	Bath Lift (hydraulic cylinder)		✔							✔	**$1, 399**
		Bath Lift (manual)		✔							✔	**$530- $570**
	Molly Bath Lift	Bath Lift	✔	✔		✔						**$2, 295**
	Kohler Elevance	Walk-in Tub	✔	✔		✔	✔		✔	✔		**$10, 476 - $11,000**
	Freedom Tub	Walk-in Tub	✔			✔	✔			✔		**$11, 240- $14,900**
	Momen-tum Bathtub	Walk-in Tub	✔	✔	✔	✔	✔			✔		**$15-00- $16,000**

Table 6. Pro and Con of Product Type

Specific Pro Learn From	Specific Con Opportunities	
+ Being inside the tub, this makes it easier for users with walkers. + There are also variations that can flip down.	- Easy to fall over in	
+ Extension makes it easier to transfer + Usually legs are adjsutable	- Even with height adjustable legs, outside tub legs are too short. - Tubs with curved edges on the inside, pushes the transfer seats to the middle, potentially pushing users body outside of tub area.	
+ Less upper body is needed to move body across	- Often still need a care giver's assistance.	
+ Less upper body strength is needed to transfer legs	- Lock is located between legs in the seat	
+ Can get into tubs lower than other lifts	- Can be extremely wobbly during sit-stand and stand-sit.	benchmark product
+ Simple, operated with a button + Suction feet adhere well to the bottom of the tub	- Not ideal for tall users- does not sit flush with back of tub. - If the hand control fails, the whole product fails - Battery costs about $300 - Weighing in at 20 lbs., reports of being too heavy	
+ Some allow for swivel + No batteries, no recharging, don't need to worry about failure	- Does not fit will with curved tubs - Water bladder is expensive to replace (if it leaks)	
+ No batteries, no recharging, don't need to worry about failure	- Crank can make it impossible for some users to enter the tub	
+ Lowers all the way to the bottom	- Belt is not sold/stable, not recommended for poor balance skills or poor ubber body strength	
+ Requires no lowering/rising + Minimal leg barrier + Heated back offered as an extra add-on	- If the seal fails to deflate, user is trapped in tub until someone can crawl under the tub and pull out the electric plug. - Might need grab bar to help move towards the middle of tub	
+ Requires no lowering/rising	- User can get cold from waiting for tub to fill and drain - Might need grab bar to help move towards the middle of tub	
+ Requires no lowering/rising + Tub does most of the work	- Chair takes up space in the bathroom - User cannot step into shower if desired	

Insight Gained:

Kohler Elevance came out as the benchmark product. Initially, when this tub was discovered, the thought was that this tub is a great example of what this thesis is aiming for. However, upon closer inspection, the design criteria that are missing are impactful criteria that are

important for a tub to be considered universal and rank high in terms of usability. For example, the Kohler Elevance fails to help a wide ranger of users enter the tub and especially rise and lower.

CHAPTER 5

IDEATION

Sketches

Initial sketches were made to ideate the concepts of moving pieces vs. moving forms, and different grab-bars designs. In the second sketch series, the focus moved to designing a tub that integrates supports, and seeing the tub as a whole. The final directions are highlighted in color. Two designers who work in the field specializing in bathroom design for older adults chose the final two designs. The two directions were then modeled in “Solidworks”. Functionally, both prototypes seem to satisfy the design criteria, however the first prototype gave the feel of parts of assistive technology thrown together and lacked design cohesiveness, so the sitting bath prototype was chosen as the final design.

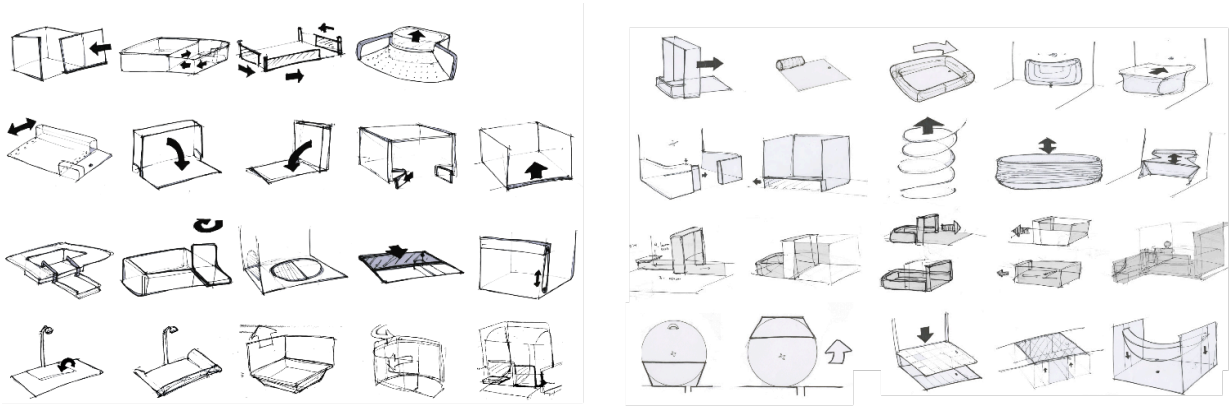


Figure 19. Initial Sketches

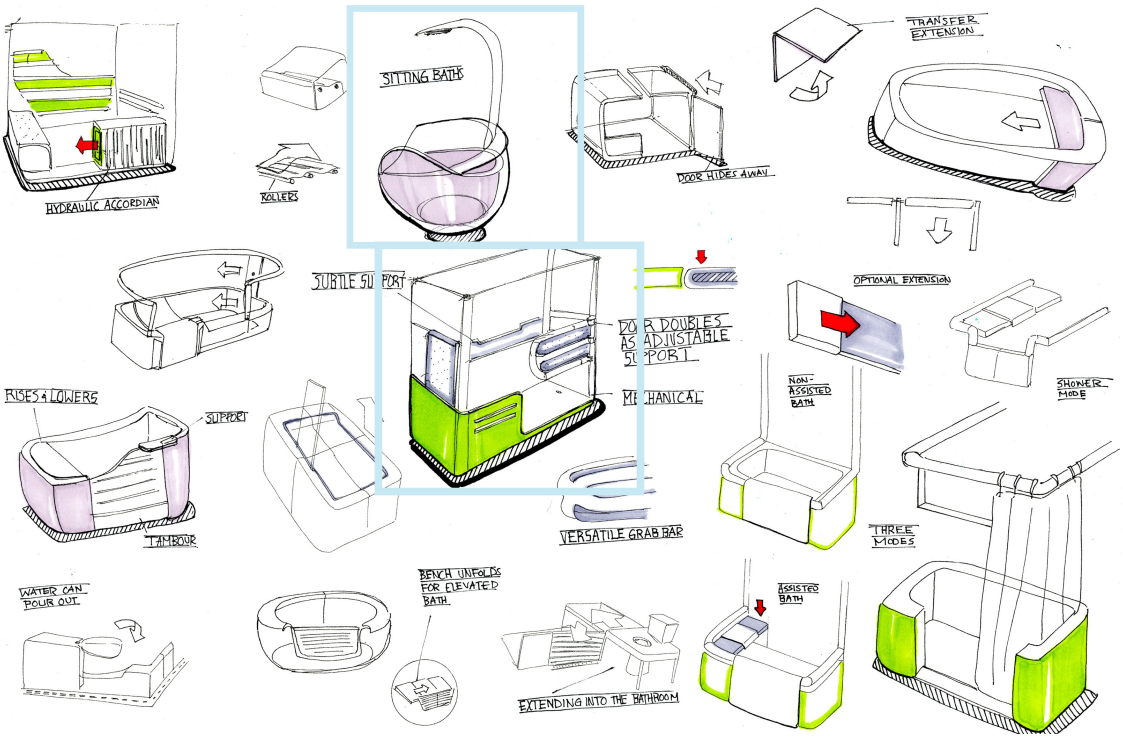


Figure 20. Integrated Tub Sketches

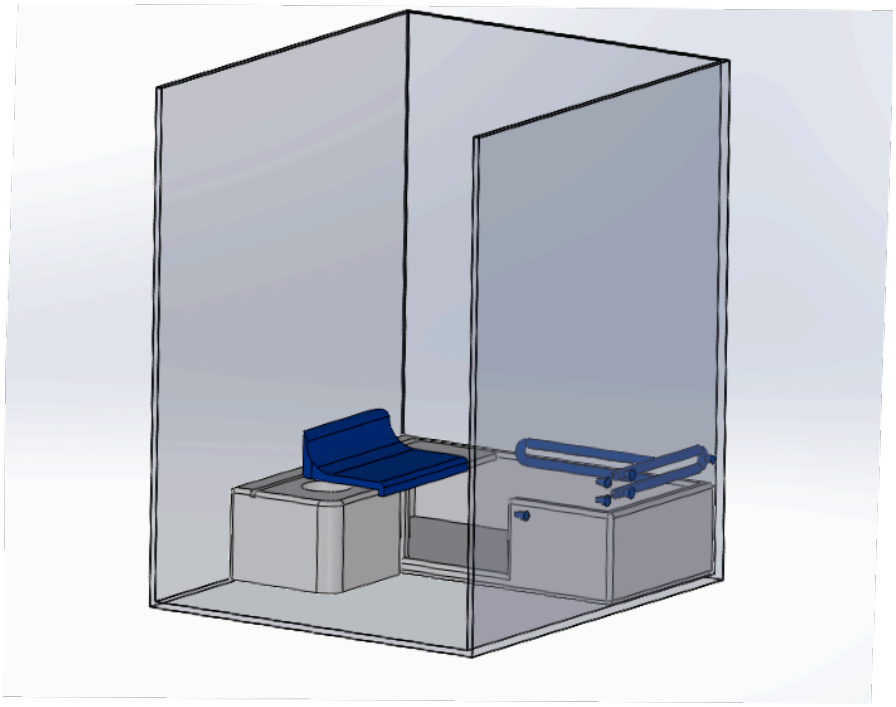


Figure 21. Integrated Tub Model 1

Figure 22. Integrated Tub Model 2, Final Model Choice

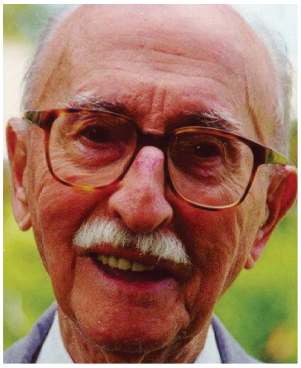
CHAPTER 6

PERSONAS AND EXPERT INTERVIEWS

Personas

In order to understand if the chosen design made sense, three personas were developed to represent the possible users. The first persona is Ruby, she represents a middle age, ambulatory user who doesn't use assistive technology but is unstable in movements, grabs anything as support, has trouble lowering into a regular tub, and gets exhausted easily. The second persona, George, represents the average older adult group who is ambulatory, uses a walker and has a weak upper body, trouble lifting legs and moves slowly. George has no fear and chooses to not lower himself into a regular tub as he loses balance easily. The third persona, Mike is representative of a younger adult who is a paraplegic with an above elbow amputation and uses a wheelchair. He has a strong upper body and uses grab bars and towels to assist with bathing. Each persona was then used in different storyboard scenarios in which they conduct bathing tasks. The personas were based on the video analysis done previously.

RUBY
Age group: Middle Age
Physical Status: Ambulatory
Daily Assistive Tech: None
Other behaviors: Unstable, grabs anything as support, trouble lowering into a regular tub, gets exhausted easily.



GEORGE
Age group: Older Adult
Physical Status: Ambulatory
Daily Assistive Tech: Walker
Other behaviors: Weak upper body, trouble lifting legs, slow, has no fear, typically does not lower into a regular tub. Unsteady hips and legs.

MIKE
Age group: Young Adult
Physical Status: Paraplegic & one above elbow amputation
Daily Assistive Tech: wheelchair
Other behaviors: Strong upper body, makes use of grab bars and towels.

Figure 23. Personas Ruby, George and Mike

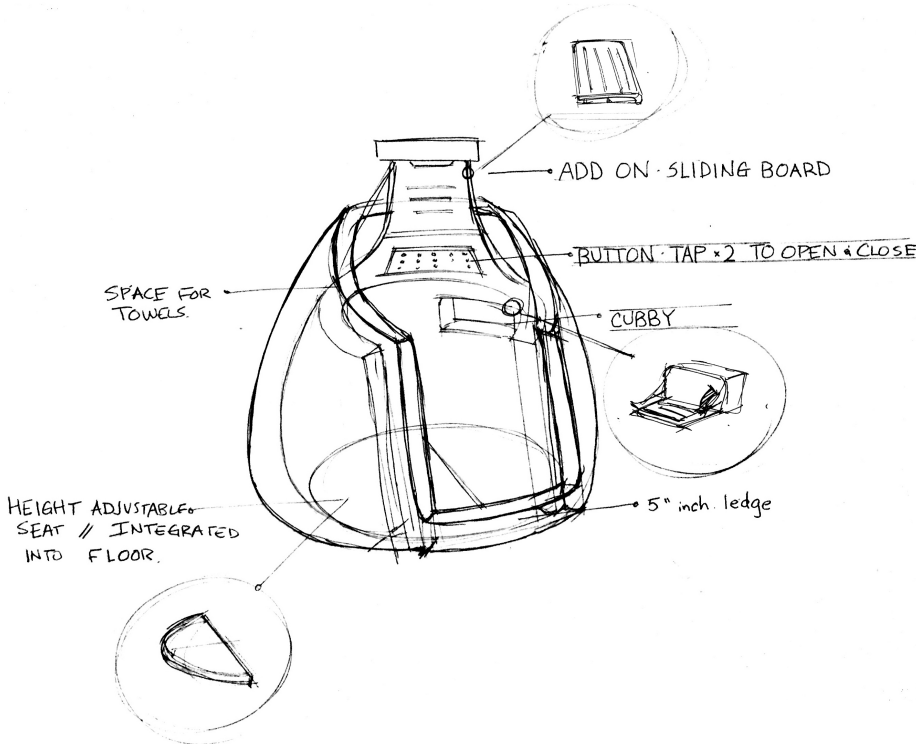


Figure 24. Prototype Concept Used in the Storyboard

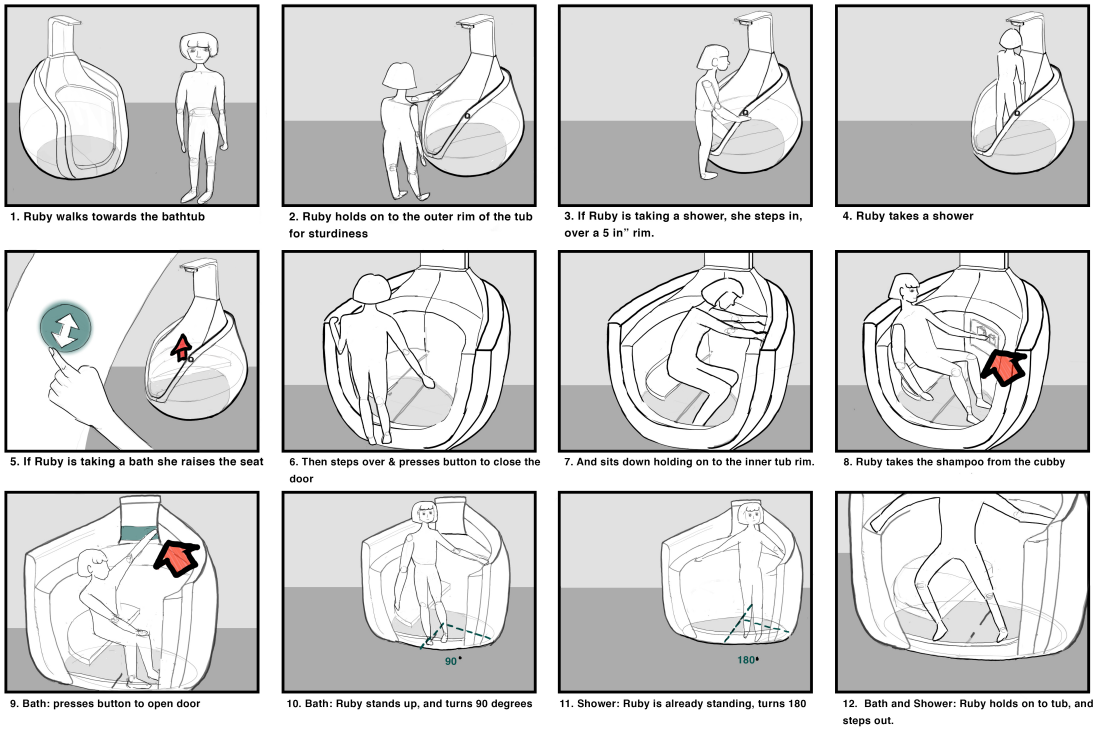


Figure 25. Persona Ruby Taking a Sitting Bath and Shower

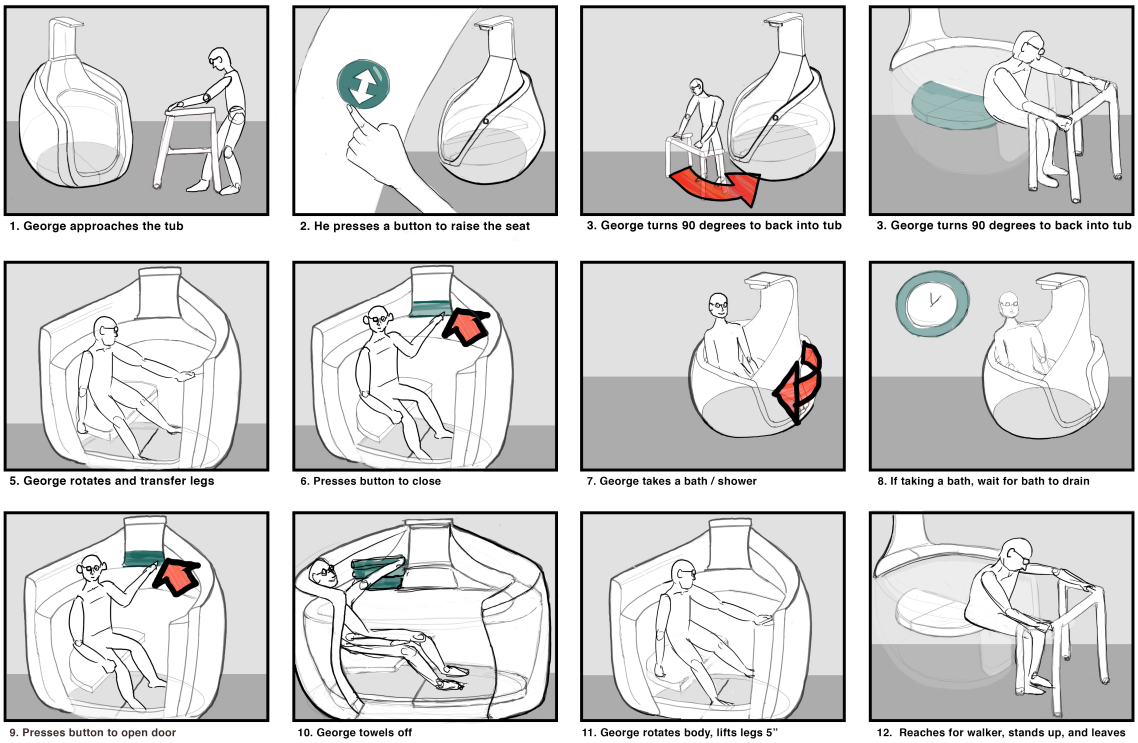


Figure 26. Persona George Taking a Sitting Bath

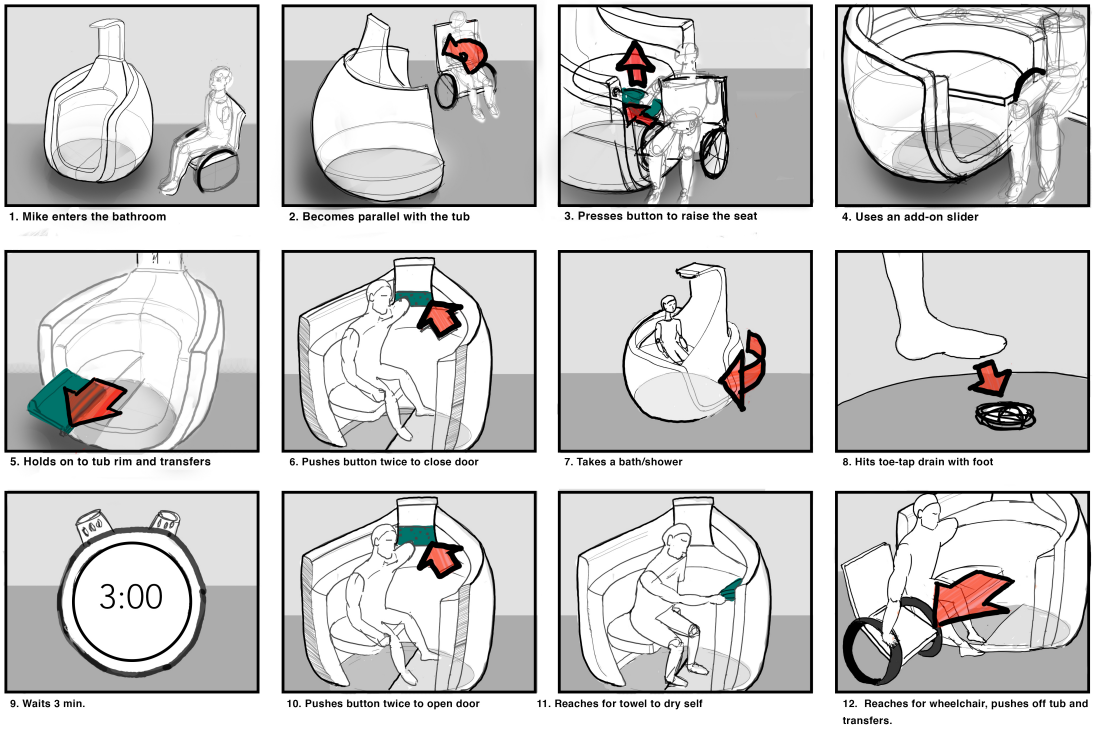


Figure 27. Persona Mike Taking a Sitting Bath

Interview

This interview of experts included 3 clinicians. Examples of clinicians are occupational therapists and physical therapist, they were chosen to interview because they are the ones that work the most intimately with assisting users.

Methods

The length of the interview took approximately forty minutes to one hour. A semi-structured interview was chosen so that I could work around a general framework but still maintain flexibility in the questioning. The informal style allows there to be deeper conversation if needed. Storyboards were presented, and then participants were asked a series of closed-ended questions (e.g. likert-scale and multiple choice) that were later coded for organization.

Open-ended questions will were included at the end of the interview to capture further insights. The interview was also audio recorded and transcribed.

Experts

Three experts in older adults were informally interviewed at their work place using an interview guide. Two of the experts were trained as occupational therapists and one expert was trained as a physical therapist; all three currently focus on older adults and those with limited mobility. Each expert was first provided with a description of each persona, then was handed one storyboard to study, and afterwards had a conversation guided by set questions. Then, the same process occurred for the remaining two storyboards. The experts were welcome to actively mark up the storyboards through the interviews. Each interview took an hour at their office and the interviews were voice recorded for further analysis.

Figure 28. Experts Reviewing Storyboards

Table 7. Content Analysis Mike

MIKE	Slider	Toe-tap Drain	Lateral Transfer W/ Shelf Surface	Reaching Forward	Button Size/Placement	Tapping Button Twice
P1	Is there something we can do to reduce his exhaustion? The biggest trouble between transferring with wheelchair is the tire. Unfortunately, the smaller the tire the harder it is to push, the farther way it is, the less efficient it is. Nobody has really come up with anything, except for a transfer board, and most people haven't been taught proper transfer techniques.	He is not going to be toe-tapping that drain.	He is going to have problems transferring from one side more so than the other because he doesn't have the balance. Whichever he got his good arm; he might use it to pull with. Looking at this picture, where he has the stump on the shelf, he could actually use it to lift up as he is pulling up on the chair. Is there any other way you think he could transfer? Well it will all be upper extremity because of his paralysis below his waist.	It goes back to the trunk stability. If he has good trunk stabilityno problem. Looking at the picture here, that could be a little far out for him. In the case a person has poor trunk stability, to any extent to which the back muscles pull the bak, that's going to be too far. This adds weight, so this would be your fulcrum down here, anytime you have weight that pulls down,that causes fulcrum point to close, you could lose balance. As long you have good upper extremity arm wise, you can compensate for it with people who lean like so when they are reaching. They might put their arm down their to reach.	Height wise, it might be a little tall. he is sort of reaching up, and I immediately start thinking up other populations, like kids and older folks. And reaching up that high is a challenge for folks like that. For him, obviously, he is just pushing his stump up there. I would think it might be a little high. Depending on his trunk stability, he could probably reach across just find. a lot depends on how close he scooted to it. Well you know how a human body works, it might be easier if it was not directly next to somebody, but let's say this arm wasn't functioning according to that view of it, you might have a bit better luck, like 45° away, not directly next to somebody. if it's next to somebody, they can get to it easily with one hand, but not the other hand.	Oh yes, depending on the length of the stump, if they had some residual stump, i don't know that the amputation would impact. Typically it doesn't impact the ability to move with the remainder, if it's at the right place, you could even bump it at the shoulder. Having said that, the 45 degree placement might no work for shoulder bumping, but you could play around with it a little bit just to get an idea.
P2	Why do you need this? There is a wheel, you cannot get the platform very close, this shape is too curved than the wheelchair cannot reach unless the shape was more flat. If the wheelchair is flush then the add-on slider is. Most of the material is plastic, and the hand will slide away. Cannot have too high of a friction, because you still need the person to slide, but you still need high friction from the other side. Because 70-80% of your body weight is on the side you are transferring to.	HOW? No. There is no way mike can hit the toe-tap drain for wheelchair users. You are thinking T level injury even. If he has ability to control his leg, he would not use a wheelchair. You must use a wheelchair, so it gives me the impression he cannot move his leg. Talking about a wheelchair group, don't use your foot.	He probably will not use the tub to support, most like he will use the seat to press. If there is a grab bar, a lot of people grab the handle on the car ceiling and window and push on it. So if there is a handle above his head, he could just use once hand. It is only one or two seconds and most strong people like Mike could handle it and it would help them. This position (that is drawn) is hard to apply force. IT's stronger in this other position, and they can do this because they do the muscle contraction.		Twice, he can probably tap the button twice at shoulder level. If he is a C level 6/5 it could be hard for him to do hand movements, but since Mike is a strong guy, no problem.	yes, if they knew what to do, and they had strength and intervention and had use of that residual limb.
P3	Typically it's somewhere between the butt and thigh, the meaty of the thigh, it has to be really in there. the position under the wheel chair where the person is sitting, it needs a lot of shifting. If the seat could move, then before he goes into the seat, he could lower it, but then when he gets out, he could raise the seat. A little bit of momentum seem to help, in a typical bathroom. Downward transfer is always a little easier.	Toe-tap drain with his foot where you might not be able to do that. I mean, you can do it, if you bring your leg, but the whole point is design is to if you considered then this won't be that way. Definitely, depending on level of paralysis, it was a regular person trying to use the bathtub, it would have to be explicit instruction, this is how you drain. I like this idea, maybe if it existed with conjuction of other design. That switch option? it is lower.	it's not whether task completion is possible or not possible, but how much physical exertion is going into this task. In a situation if you are attempting a bath transfer. This being at an angle, the seat perhaps being a little lower, the things you can kinda manipule in the features of the environment would kind of cover it.	When the person sits up, the center of mass is here, and the way you drew it here, that's fine, we do this all the time. His body right here , but if he had to bend too far. If the certain of gravity is way off then it's potentially a gravit risky. It's okay saftey wise, he should stop if he is wobbly.	I think it's fine, the principal of proximity, better than distal in far of reach and minimizing the risk in terms of balance issues. I wonder though, how techy it's going to be, but voice activated.	yes, if they knew what to do, and they had strength and intervention and had use of that residual limb

Table 8. Content Analysis Summary Mike

MIKE	Slider	Toe-tap Drain	Lateral Transfer W/ Shelf Surface	Reaching Forward	Button Size/Placement	Tapping Button Twice
P1						
P2						
P3						

Table 9. Content Analysis George

George	Button placement for seat	Transferring correctly	Form	Transfering in if George waa hemipergia on the left side
P1	Whatever side the seat is on, because you don't have to run electrical wires all across the tub, underneath it, or ove/ behind the shower. The button to be in a convenient location,and that's it's able to be operated with not a lot of strength.	Get rid of the walker, the walker doesn't provide any stability for sitting down. If you are using the walker properly, it is pushed up against the tub. You want to keep the body within the frame as much as possible.	the diagonal edge works well	There will be a weaker side
P2	Placement is okay, it depends if he is a right hand or left hand user, which is his dominant side.	I doubt he will rotate 90°. To go backward it is very unstable and he doesn't know the distance, trip over the ledge and fall back. don't know how he can just sit on the tub, because it's just a circle. If he has unstable hip and leg due to muscle weakness. He will probably enter from the side, grab the bar, and tried to sit.	A circular looks more stylish, but a square is more intuitive so he could estimate the size easier. The form might be too tight, the opening could be larger.	No way. For this problem, he has no problem to reach. You mentioned he has no fear, he will try as quickly as possible and does not care about standard procedure. 70% he will not follow your protocol. Will fall one or two times and then learn. It depends if you high muscle tone or low muscle tone. The subject probably can stand okay, but to sit or rotate it's very difficult.
P3	If it's within your shoulder where you don't have to bend over, i would say that's a fair game as far as position goes. Slightly above his elbow level right?	There is pretty much one safe way,You typically backup till the back of your knees are touching the surface. You want to minimize movement. As far as this tub, being a different design that might not make as much sense. They just do what they aren't suppose to. If it works for them, it works for them.	If this form was more flat, he would be able to do that method.	Yes, definitely. Is the seat on one side? It would be cool if it could rotate around, given the choice, you would want someone to be leading with their strong side.

Table 10. Content Analysis Summary George

George	Button placement for seat	Transferring correctly	Form	Transfering in if George waa hemipergia on the left side
P1				
P2				
P3				

Table 11. Content Analysis Ruby

Ruby	Using the rim as a bar	5" step	Shower cubby	Adequate Support for Turning	Outer Form/Angle
P1	If it's too wide, you get a weak grasp. If it's too narrow, you get a weak grasp, so you want to make sure there is not too much of it in order to grab it. You need something you can comfortably grab on to and not get stressed by the tension that you could lose your grip.	Since Ruby has good lower ambulatory, she is unstable, but it doesn't say anything about her not being able to lift her legs. 5" inches should not be an issue for her.	There will always be a tendency for someone to reach and grab it and use it to haul up with. So you will need to take that into consideration when making it into construction. The other thing about any recessed area in general, you have to figure out the space that makes it sufficient.	The way you are showing her turn. Where she is gripping the shelf surface, the upward part of it. The farther apart the walls are, the less stability, there is potential for less stability, but at the same time, you have two walls to hold onto.	It's nice to have a selection of heights of which to grab. It's not unusual to see angles because it allows you to go from a seated position and as you stand up, at a more comfortable height for balance. More stable grip a little higher, because it is above the center of gravity. But if it's too high, you can't use it when you are sitting down.
P2	I think the bar is only useful when she steps in, but not inside the tub	If she can grab something, she can definitely step 5", for Ruby it is no problem	If she is tilting over 60° it will be hard to get back. The only way she can get back is if she has something from this side. If she grab this one, because right now if she has the door closed, she could probably grab something.	Bar doesn't help when she tries to rotate, only tries to steady. If it is too far away, she can grab the bar but cannot sit, if you make the it too close it is hard to move. My major concern is the material.The top is really slippery because there is always water. You need to make something that provides enough friction.	Concerning the form of the outer shell of the tub: which part does she grab? it seems like she can only grab the upper portion. If she presses really hard, her hand will slide down. So she can only grab at the very top. The diagonal bar is not safe.
P3	This is giving you something to hold on to. But as far as assisting sit and stand, I'm not really sure how helpful that would be. Because if she had enough strength, she would be able to. But you could probably make it a lot more comfortable.	Given your description, probably no problem. I mean, but if it was like a, you weren't paying attention, and it was like oh shit, you just tripped over a curb. yeah.	Would't this be submerged into the water? It's like floating shampoo?	Ruby could feel a little less balanced one day, and not. But i think that's just Ruby knowing herself and when does she need to avoid when she really feels unsafe, because i don't think she should be doing this if she felt really unsafe if she was wobbly, at least by herself.	I think even when there is a specific fixture, it depends on how slippery it is. And you are trying to prevent yourself from falling. There have been some near-miss when I was trying to grab them.

Table 12. Content Analysis Summary Ruby

Ruby	Using the rim as a bar	5" step	Shower cubby	Adequate Support for Turning	Outer Form/Angle
P1					
P2					
P3					

Insights from Experts

Transferring:

After the interview, there were several changes made to the prototype. First, there are several things related to transferring that was learned. To improve transferring in and out of the tub, the tub transfer board that is a flat board that assists in bridging the gap between the tub and the wheelchair, was taken out as a potential addition to the product. It was viewed as not useful by two of the experts and suggested as an potential option if it was redesigned. Because the wheelchair wheel is a barrier for transferring, it is difficult for users to situate transfer boards properly, and need proper training that most users do not have (this could be a future design concept that would need further investigation).

Form:

The original tub design was originally round, providing an aesthetically pleasing look, however the front of the tub was changed to a flat surface so that users can have a more intuitive transfer, especially for wheelchair and walker users. Experts voiced how the form and current supports offered assists with entering and exiting, but questioned the usefulness in turning and sitting down. Depending on the user's mobility limitations rotating can be a very hard task.

Supports:

Currently, the tub is made of two shells. The outer shell rotates and seals water, but also acts as a support for users. Initially, the outer shell was mainly configured at a horizontal level with the outer parts sloped in a diagonal manner. One of the experts found this to be a great idea, as the expert explained that shower users use a diagonal bar. In addition, this bar allows for users to use it when they are sitting, standing, and sit-to-stand, stand-to-sit transfer. Another expert thought that the user would only be able to use the flat upper portion, otherwise their hand would slip down, and the user would fall. The idea of having a stepped form came to mind. Other suggestions were discovered, as specific questions concerning the personas doing specific tasks (i.e., Ruby is reaching for the towel, do you this she can do this?) were discovered. There were consistent suggestions among the experts to add supports along the side of the tub and above the head (similar to how users transfer into car) were suggested to assist with transferring. It was also suggested that a bar in front of the user would be useful in case a user bent over too far (straightening up from angles past 60 degrees is incredibly difficult) and couldn't get back up.

Concept:

During the interview, there was a strong underlying concept that although a user could perform a task, the main concern is for their physical exertion, and therefore everything should be proximal to the user.

Corrections:

Although one of the transfer videos that I watched a user similar to George transfers from a walker to the tub backwards, I learned that this is in an unsafe way to transfer into the tub. Concerning the persona George and other walker users, the best ways to transfer are

sideways and leaving the wheelchair away from the tub. This is because the walker does not provide any stability for sitting down, and moving into a tub backwards when a person has an unstable hip and leg due to muscle weakness is very unstable. I also learned that in the case that users do transfer this way, users are taught to back up all the way until the back of their knees touch the material. A round front edge of the tub would make this task even more unsafe than is already is. More over, transferring sideways with a round edge would be equally difficult.

Another correction was with Mike's storyboard. Even though Mike was paraplegic, the thought was that he could still move his working leg or manually use his leg to hit the toe-tap drain. While one of the experts admitted that this was an option, the expert also noted that if this was a designed product, the user shouldn't have to do that. The other experts noted that under no circumstance was this possible. If a user is in a wheelchair, a design should not require them to do anything with legs. It was also learned that some subjects have no feelings in their legs. Therefore, in order to include users with weaker lower body strength, the toe-tap drain option could not be the only way to open and close the drain. Therefore, another touch option for the drain was added.

There was another correction in Mike's storyboard. Although I saw many users transfer at an angle during the videos, I did not realize that this is the trained way to transfer, and so in the storyboard, Mike transferred parallel to the tub. All three experts reported Mike transferring incorrectly, and that he should be transferring at the standard 30-degree angle for easier transfer; the term for this is called angular displacement.

Material:

Concerning handgrips, seating, and the risk of slipping, material was a large concern for many of the experts and can be noted for future study.

Summary:

The expert interview gave me very useful feedback on the design and a lot was learned from the experts that I did not read from the literature review. Furthermore, I was able to connect some of the observations that gave me abstract concepts with the feedback from the occupational therapist/physical therapists that made those abstract concepts into concrete knowledge (i.e., transferring at an angle).

CHAPTER 7

INITIAL PROTOTYPE AND DESIGN CONSIDERATIONS

INITIAL PROTOTYPE

More sketches were made to accommodate the changes learned from the expert interviews. Sketches to explore mechanisms were also created. An initial prototype was designed in order to understand the space and different forms of the design. Three forms that were in question are pictured below. One of the forms was designed based on idea the form curves in to provide upper body support, while allowing the lower body to pivot as needed in a larger space. Another form was based off of office chairs that provide lumbar support. For the purpose of having a more structural prototype, a straight form was chosen, and if needed, the form and aesthetics could be revisited after the usability test. The outer rotating shell was removed after consultation with mechanical engineers.

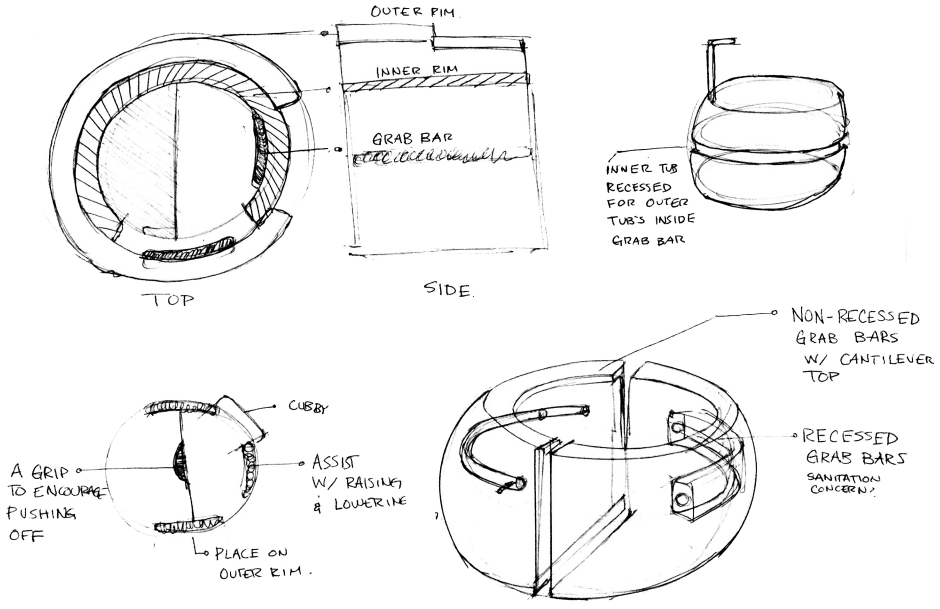


Figure 29. Sketches Based On Expert Interviews

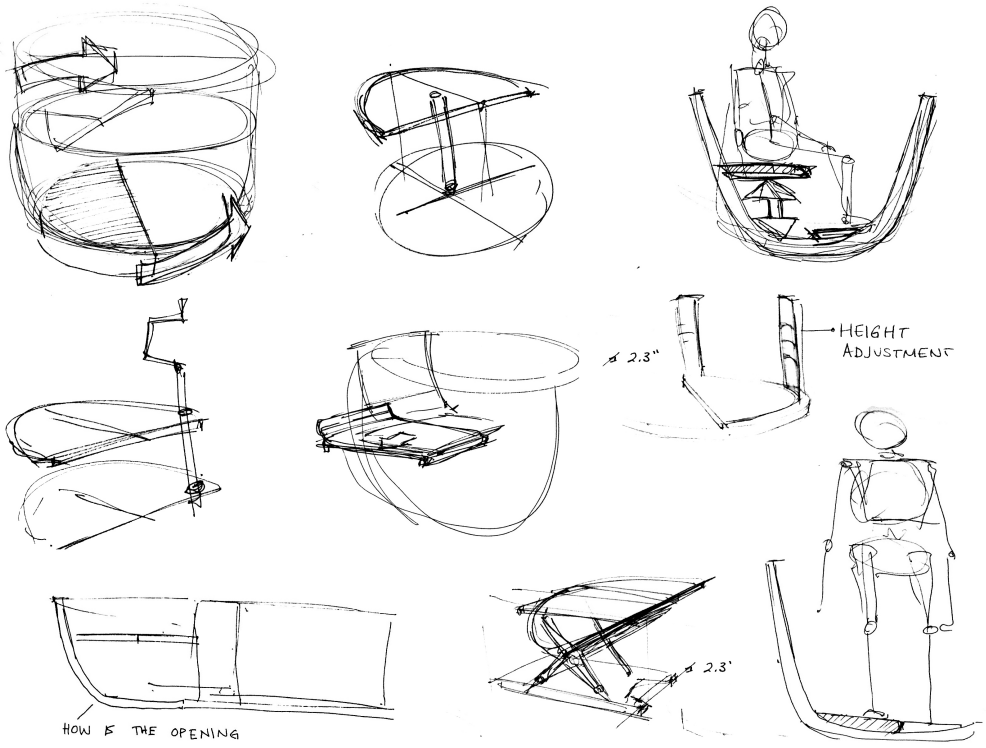


Figure 30. Sketches on Design Mechanisms

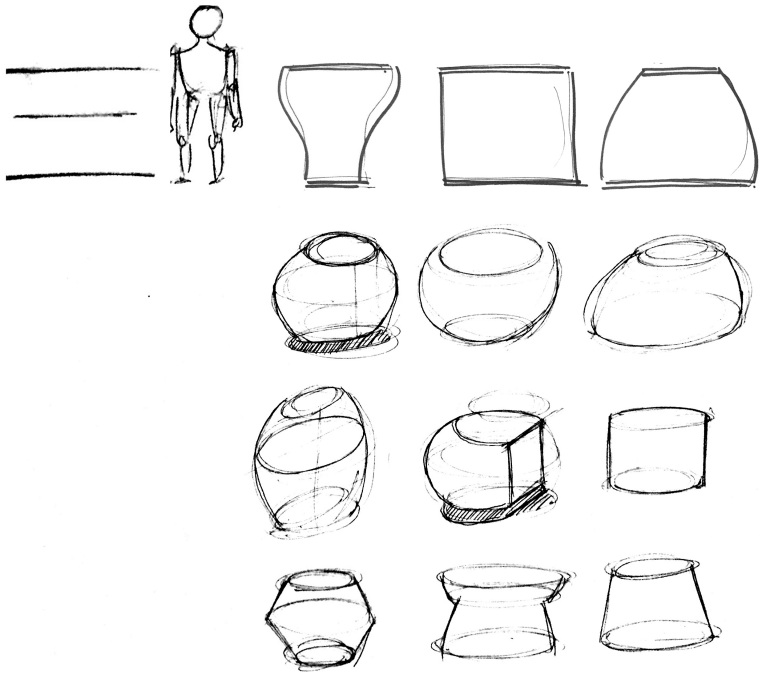


Figure 31. Form ideations

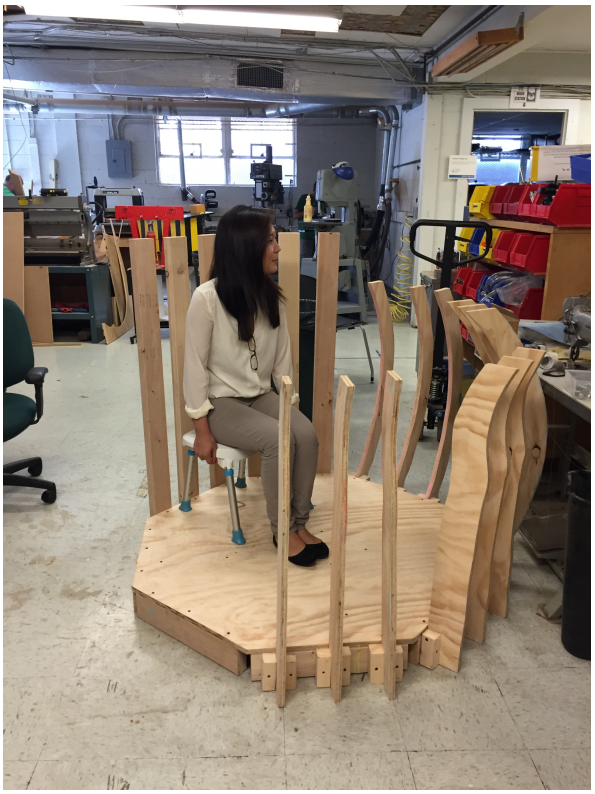


Figure 32. Initial Prototype

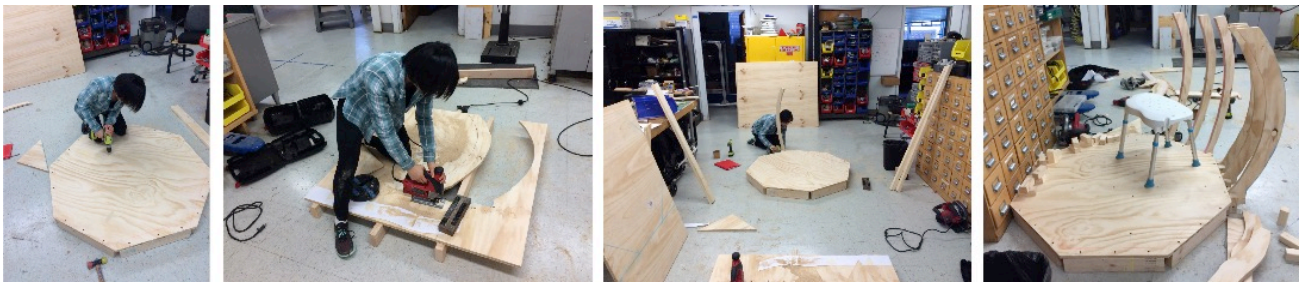


Figure 33. Prototype 1 Process Photos

Prototype Considerations

The final form that was tested on users was made of a combination of design inspiration, specific preferred measurements and bathtub fixture suggestions from the literature,

interviews feedback of transfer scenarios based off of observation, and finally basic ergonomic guidelines. The goal was to reduce as much movement as possible.

It was important to test out these combinations of chosen features to understand if this design will provide for users as intended. In order to decide what was important to test in Prototype 1, a matrix was created from the design criteria and the informal interviews to form the hypothesis, overarching design goals, design strategy, prototype strategy, what is being tested, and the specific way to measure it. These specific design strategies were chosen as a method to fulfill the first goal of having an easier transfer: 1. Barriers will be eliminated for legs, having the option of a seated transfer to bathe, and having an entire tub that provides upper body support within the proximal space.

Rational behind the features

A seat for a sitting bath allows for this type of support. In addition, "Universal Design as a rehabilitation Strategy, Sanford) cites that in a survey of 700 older adults, that they had less difficulty using fixtures with a seat than those without a seat. And that larger percentages of respondents reported that showers without seats, including curbless showers without a seat (41%), were more difficult to use than either of the two bathtubs with seat. If the distance a person must lower could be reduced, this could also decrease the risk of falling. The more supports located around a person, the less likely they are to slip. The backrest affects the users comfort. If the backrest is more vertical, the higher the sides will have to be to allow the body to be fully under water, and the back rest affects the users comfort (Kira, 1976).

Table 13. Design Goals

DESIGN GOALS	1. Easier Transfer			2. Better Usability for Bathing Tasks			
DESIGN STRATEGY	1a Eliminates Barriers for legs	1b Seated Transfer to bathe	1c Entire tub provides upper body support	2a Drain button & toe tap option	2b All bathing activities are within reach	2c Door provides no difficulties to use	2e Intuitive
Hypothesis/ Design Criteria	Do legs hit anything? Clear structure without contact i.e. door, opening,	Ambulatory users will walk in and then sit. Non-ambulatory will perform seated transfers. Is there surface area? Do they slip?	Providing hands holds/Do they touch where I intend them to?	Toe-tap is most convenient where? Preferable to a button?	Which area is most convenient for users to grab items? Side/Front/Diagonal? Moveable something. Enable something to go to it.		
How to Make	Hardwood structure	Use chair or make own	Create several "shelves"	Prototype a simple looks like toe-tap drain	Hardwood Structure	Wood structure, and some kind of sliding system	Sensory Details
How to Test	Ask user to transfer / soap arms and legs	Ask users to enter and sit	Part of transfer/sit to stand process		Act out tasks: turn on water, reach for soap	As users touches button, I manually move door	The tasks
How to Measure	Observations & Likert: Difficulty in and out	Observations Touch points & Likert: Difficulty sit to stand	Observations Touch points & Survey		Observations Touch points	Interview? Observation	Observe Errors and Success Rate

CHAPTER 8

PROTOTYPE & USER TESTING

User Testing Methodology

Based on the user testing, a final design was chosen and refined for a full-scale prototype. As part of the last phase, a usability test using the prototype was conducted in order to evaluate the final design.

Usability Testing

Participants included one pilot test and 17 people, with some sort of motor limitations who use devices to bathe. Due to risk factors, participants who could not transfer independently were excluded.

Methods

The usability test used a full-scale prototype and took about 1 hour. The prototype did not feature running water, but other features that were essential to the design were functional. The tasks required the participant to approach the tub and use it to perform the actions of bathing. Metrics that were included in this usability evaluation were completion rate (to measure task success or task failure); usability problems (to measure which user encountered which problem); task level satisfaction; errors (to measure slips, unaccounted for actions, etc.) and touch points.

Figure 34. Testing Setup

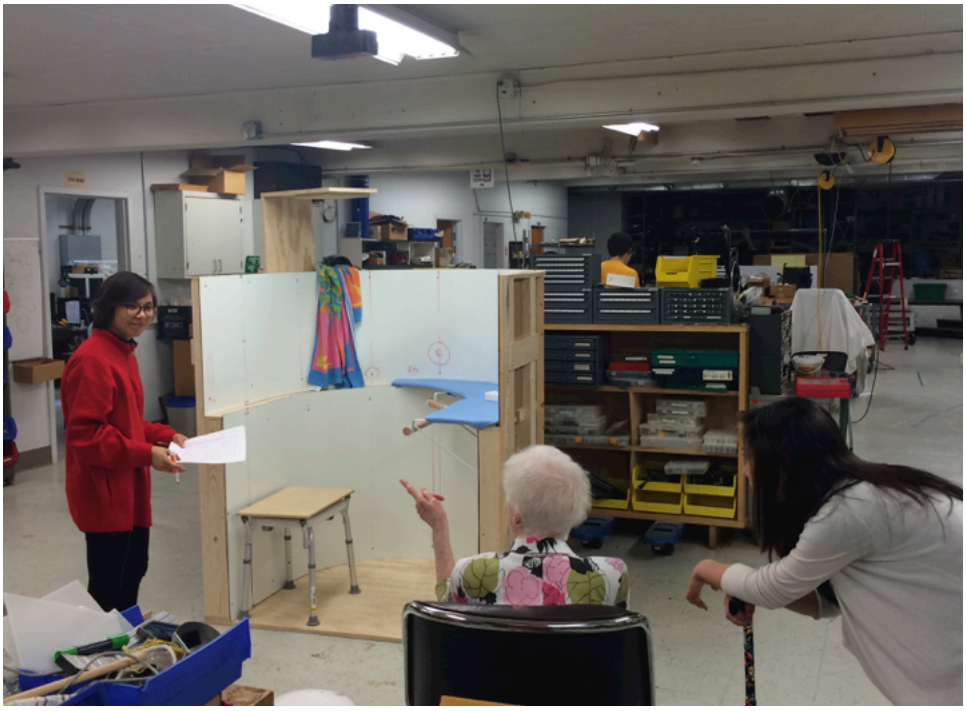


Figure 35. Testing

Figure 36. Prototype 1 Testing

Figure 37. Prototype 1 With Modifications Testing

Results

Background

The age of the users ranged from 65-87 years. 88% of users use a shower at home because they felt cleaner, while 47% of users would bathe if it were easier. Only two users had both a separate shower and bathtub. 18% of users used shower benches in their shower stalls and one user occasionally wears an emergency necklace. 23% users did not use a grab bar, 12% users did not use a grab bar but wanted one, and 64% of the users had grab bars in their tub/shower. This shows that there are users who need support but do not necessarily provide

safe support for themselves. If the tub included integrated support, this could be a good method to prevent the risk of falls. Despite users being fairly agile, there were a high number of touches when entering. Overall, ease of entrance and exit into the tub ratings improved 64% and ease of entrance and exit into the shower ratings improved by 25%.

Table 14. Ease of entrance and exit comparison between a regular bathtub and the new product as a tub

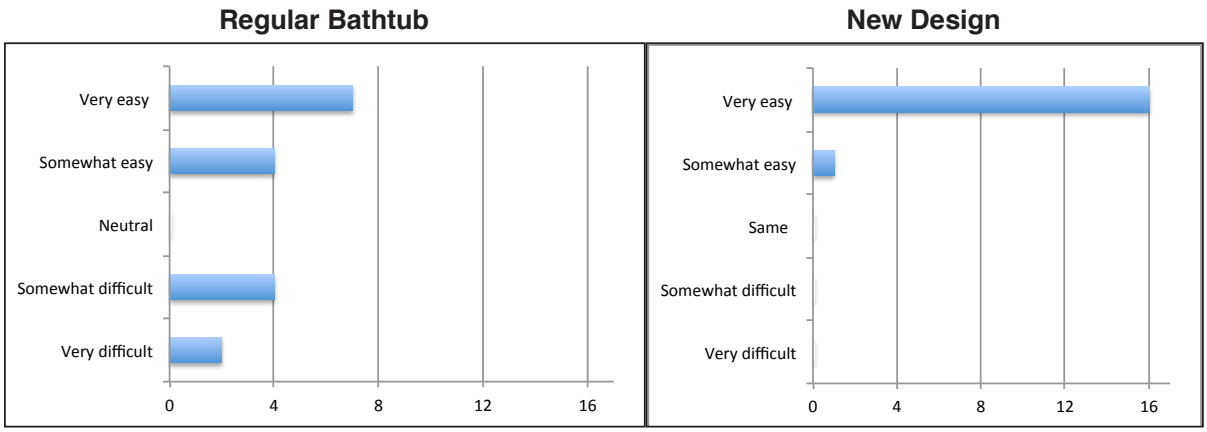
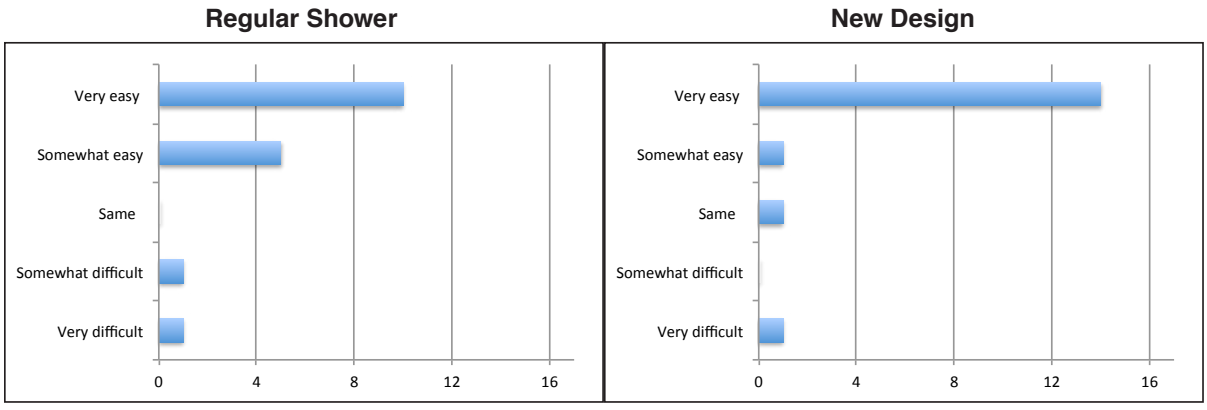


Table 15. Ease of entrance and exit comparison between a regular shower and the new product as a shower



Prototype 1

Figure 38 shows how touch points were analyzed. The objective of the tub ratings matrix is to pinpoint where there is difficulty and what works well (Table 15). This was especially useful to help in deciding what parts of the tub to modify for Prototype 1 with modifications. Some of the data (towel and soap placement) that was analyzed proved to not be as important as the other factors and so was taken out, modifying the usability test. The idea of the outer shell being at a diagonal slope or as a flat surface for gripping was not warmly accepted, and so it was not tested in the next round of user testing. Many users had a desire for more supports, and there was a general consensus on the location of the supports. During the soaping tasks, it was revealed that users either didn't soap their feet because it was too difficult, sat on a shower bench, or used a brush. During the testing, it was observed that many users held on to the bar to support themselves and would find it helpful if there was a support for their feet. Therefore, a support for the feet was added.

Prototype 1 with Modifications

The data shows that the additional supports added to prototype 2 were well received, and felt the supports were enough. At any point if they suddenly wanted to hold on to the grab bar, they felt very safe in the new design tub. However, users that needed the additional support preferred a bar to integrated shelving or a textured flat surface. This reason is mainly because those specific users felt bars were "safer", and they did not care about aesthetics. The users who did not need support to sit or stand liked the idea of the integrated shelving and bar. The data shows that some users found the shower to be very similar to the ones they use at home,

especially if their tub was outfitted with home modifications. The choice to move all the controls to one place was also a good choice, and a touch faucet was something that the users enjoyed. After the testing, several users cited that they should have grab bars, but they don't currently have them installed at home. After the study several users cited that they would go home and add grab bars and shower chairs to assist them shower and bathing tasks. Tables 19 shows that there were 42 more touch points total on the prototype 1 with modifications compared to the first prototype created with no modifications. I postulate that the reason for this is that more useful supports were added. It can be seen that there were less touch points used on the outside grab bar, but instead the touches were "distributed" to the other grab bars that were added. Table 20 is total touches per action, which helps evaluates the importance of each action depending on the task.

KEY
1 = entering
2= standing at rest
3 = stand to sit
4 = sitting at rest
5 = soaping
6 = sit to stand
7 = exiting

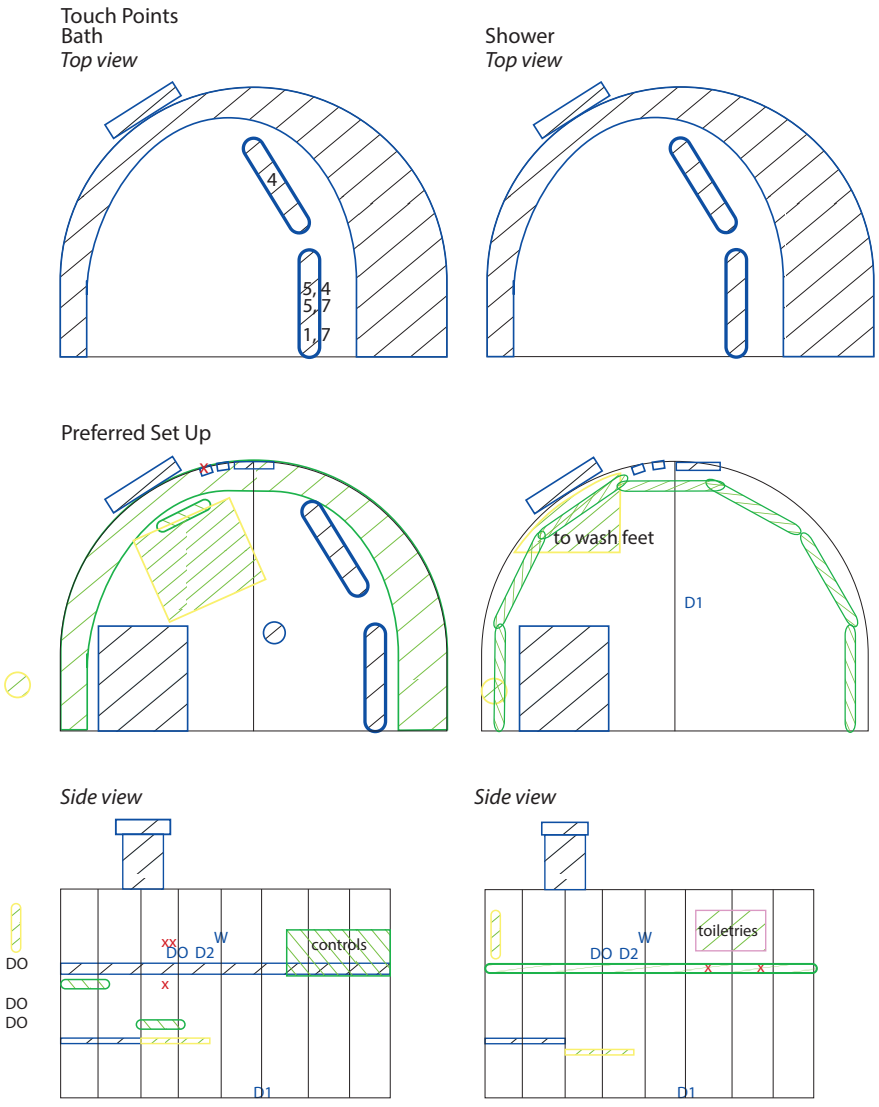


Figure 38. Coding Touch Points

Table 16. Prototype 1 Tub Ratings Matrix

Tub: Prototype 1 Testing Ratings	Enter	Toe Tap	Close	Water	Grab Soap	Soap	on/off drain	towel	exit	
P4	1	1	1	1	1	1	2	4	1	
P5	1	1		3	3	1	4	3	1	
P6	1	1	5	4	1	2	5	1	1	
P7	1	1		4	3	1	2	3	1	
P8	1	1		1	1	1	1	1	1	
P9	1	1	1	1	1	1	1	1	1	

Table 17. Prototype 1 Shower Ratings Matrix

Shower: Prototype 1 Testing Ratings	Enter	Toe Tap	Close	Water	Grab Soap	Soap	on/off drain	towel	exit
P4	1			2	1	1		1	1
P5	1			3	1	1		3	1
P6	2			3	4	2		1	2
P7	3			2	3	3		3	1
P8	1			1	1	1		1	1
P9	1			1	1	1		4	1

Table 18. Prototype 1 with Modifications Tub Ratings Matrix

Tub: Prototype 2 Testing Ratings	Enter	Toe Tap	Close	Water	Grab Soap	Soap	on/off drain	towel	exit
P10	1	1	3	2			1		1
P11									
P12	1	1		1			2		1
P13	1	1		5			1		1
P14	1	1 or 2	3	3			1		1
P15	2	1	1	1			1		1
P16	1	1	1	1			1		1
P17	1	3	1	1			1		1
P18	1	2	1	2			2		1
P19	1	1		3			1		1

Table 19. Prototype 1 with Modifications Shower Ratings Matrix

Shower: Prototype 2 Testing Ratings	Enter	Toe Tap	Close	Water	Grab Soap	Soap	on/off drain	towel	exit
P10	1			1					1
P11									
P12	1			1					1
P13	1			1			1		5
P14	1			2			1		1
P15	1			2					1
P16	1			1			1		1
P17	1			3					1
P18	1			1					1
P19	1			1			1		1

Table 20. Ranking Most Used Supports

9 subjects

Ranking	Prototype 1 Support, Ranked by Touch Point Quantity	
1	outside grab bar	50
2	inside grab bar	6
3	shelving	7
	seat	1
	total	64

9 subjects

Ranking	Prototype 1 With Modifications Support, Ranked by Touch Point Quantity	
1	outside grab bar	36
2	inside grab bar	17
3	bars	17
4	vertical grab bar	16
5	footrest	13
	table	3
	shelving	3
	seat	1
	total	106

Table 21. Total Touches Per Action

Prototype	Tub:Touch per action	Shower: Touch per action	Total Touches per action
entering	9	7	16
standing at rest	4	9	13
stand to sit	5	0	5
sitting at rest	6	0	6
soaping	4	4	8
sit to stand	5	1	6
exiting	5	4	9
turning on water	0	1	1
total	38	26	64

Prototype with Modifications	Tub:Touch per action	Shower: Touch per action	Total Touches per action
entering	8	16	24
standing at rest	7	16	23
stand to sit	2	0	2
sitting at rest	5	3	8
soaping	6	13	19
sit to stand	3	1	4
exiting	7	7	14
turning on water	0	0	0
total	38	56	94

Final Concepts

The side table was ultimately removed, as it was useful for some but cumbersome for most people. If users wanted to take a seated shower, they can raise the whole bench. As the shelving width has been reduced, the footrest will suffice for shower users who want to wash their feet. The grab bars were retained; an integrated soap dish was added into the shelving, as well as holes in the shelving and footrest to allow water to drain. The lower grab bars next

to the controls proved to be a good height. They were replaced with extendable bars for two main reasons. The first one is to accommodate different reach lengths and the second is to allow shower users to have more space. The function of the raising and lowering seat was something users liked. Most users preferred the toe-tap drain; of those who didn't; they either had no preference, or had bad experiences with the toe-tap drain not working properly (this could also be something to examine in the future).

Design Criteria Evaluation

To review, the following design criteria was developed based off of the literature review and the observations, it was found that while there were new discoveries from the expert interview and the usability testing, this process only backed up the design criteria.

1. Eliminate barriers for legs

a. If users transfer laterally by themselves: quadrant 0-1 should be below 15" inches.

b. Quadrant 1-2 should be below 5" inches.

c. Barrier quadrant for legs: (2, 1.75, 0 to 1)

In the expert interview and usability testing, the experts and users comments about how useful it was to not have a barrier. There was one user who voiced concern that there needed to be a rim or else the water would leak on to the floor.

The final concept will still not have a rim, as it is a tripping hazard, and will allow more users to use this product. For this purpose it would be worth it to do further investigation on the sealing of the door so that there can be minimal threshold when entering and exiting.

2. Tub should include support for upper body

a. Front bars if user needs to lift legs to enter/exit

b. If users transfer laterally by themselves

c. To assist with cleaning body parts

d. To lower and raise oneself into water

The prototype presented to the experts had an outer shell that could provide grip for the users. The experts deemed that it could be useful, depending on the form, of which the experts had differing feedback on the usefulness of this (a horizontal compared to diagonal form). However, during the usability testing, users did not see the purpose of this, and so it was taken out. From the expert interview, it was learned that bars in front and to the side would be useful to help with entering and if needed, reaching. the usefulness of front bars at waist level was apparent, in the first prototype, however users reported needing more support when entering, mainly, left and right at elbow and shoulder level near the openings. It was also suggested that instead of using shelving, a bar was added all around the shower portion of the product. With these additional supports added, the second modified prototype proved that these were useful additions. With this specific user group, this was enough support for the upper body.

3. Should be an integrated fit in the environment, socially and physically

a. The tub should be usable by a wide range of users regardless of mobility without impeding others.

4. Users must be able to take a bath and a shower

a. Must hold water (soak: water level is up to belly; bath: water level is up to chest

Although most of the users tested were shower users, those that would take a bath if they

could physically bathe, would use this product as a tub. There were concerns in regards to water consumption. Testing four different bathtubs, I know that smaller tubs need about 30 gallons of water and a regular tub needs about 60 gallons of water. At this point in time, this bath would take about 110 gallons of water to reach the chest, which is approximately the amount a large bathtub or whirlpool would take. The extra 50 gallons of extra water needed compared to a regular tub could be a draw back for environmentally friendly consumers and on the environment in general. Below is a diagram of the measurements that allowed me to calculate the amount of water needed for this tub.

5. Form should coincide with assistive technology (i.e. walker/wheelchair)

a. The form should accommodate seated transfers, in most cases, and wheelchair users.

b. The form should not have parts that jut out or impede users (e.g. walker users, wheelchair users, etc.)

From the expert interview, the shape of the tub was modified in order to coincide with assistive technology. However, it was difficult to recruit users with walkers and wheelchairs willing to do this study. There was a user who gave comments with her daughter in mind, an above the knee paraplegic who uses a wheelchair and felt that this product would fit her daughter fine. Unfortunately, it remains unproven whether this form can coincide with assistive technology.

6. Should fit the U.S. average bathroom size of 5' x 8'

This decision was made to expand the number of users that would buy/use the tub. There were ranges of concerns as to how this large form would fit in their bathroom. Others thought it would fit in their bathroom just fine, and that it saved space because it had the dual

functionality of both a shower and bathtub. Other suggested this type of product is more suited for a health gym. Figure 40 demonstrates how it could fit in a regular bathroom:

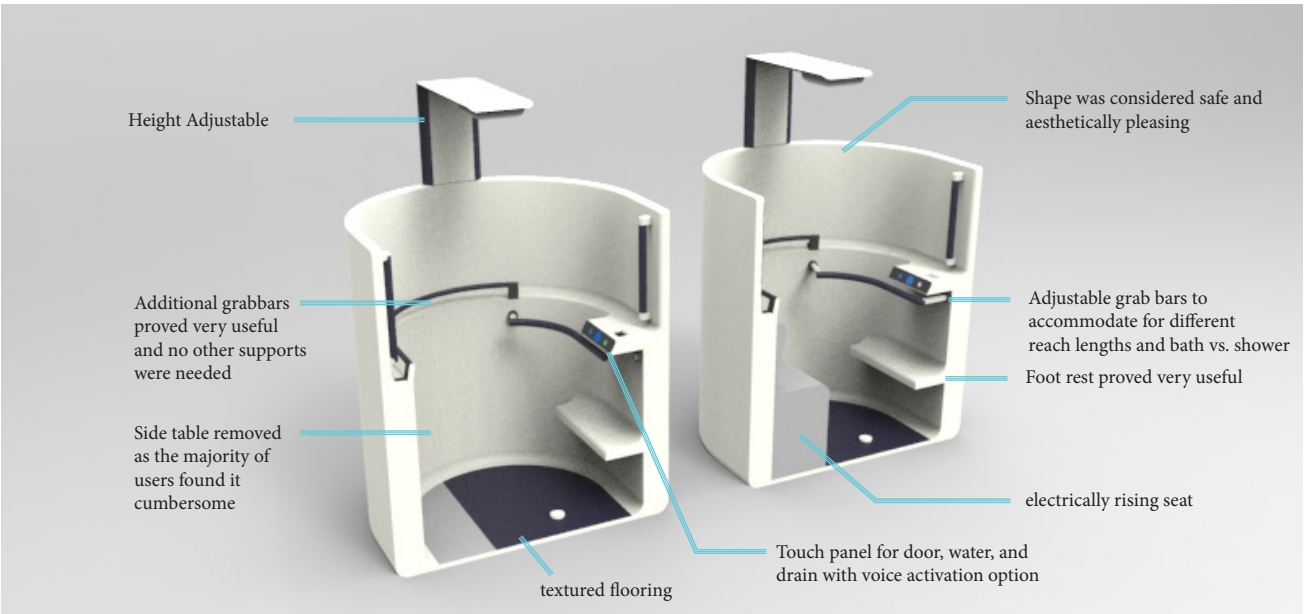


Figure 39. Final Design

Figure 40. Final Design in 5’ x 8’ Bathroom Setups

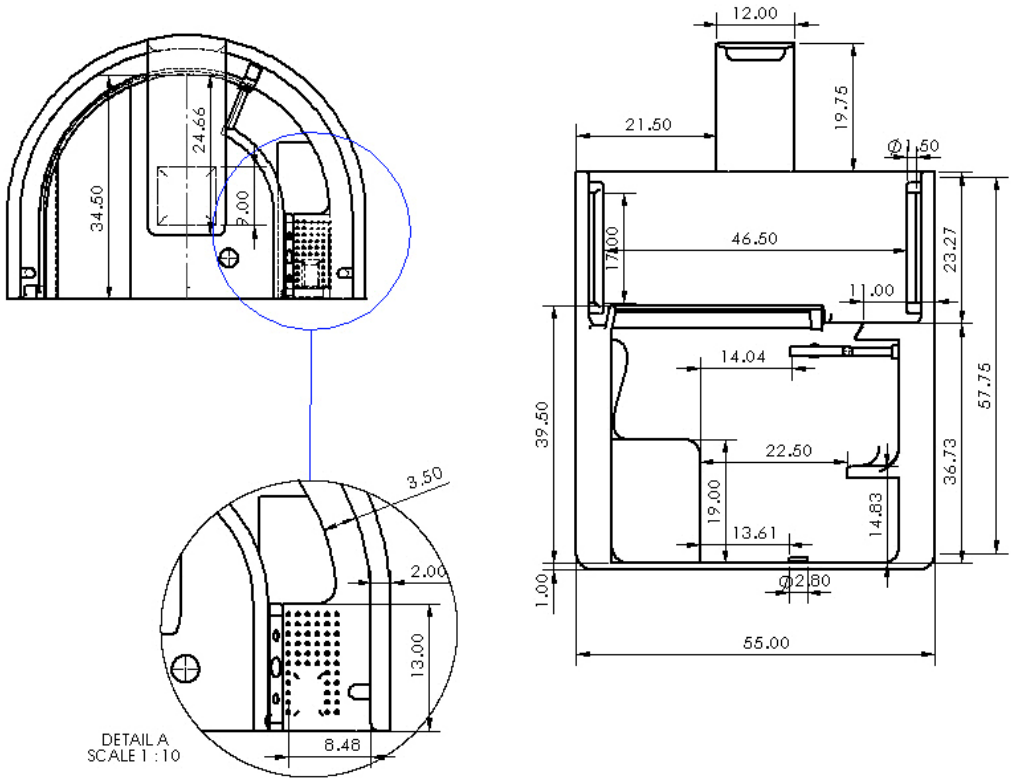


Figure 41. Final Design Dimensions

Conclusions

The location of the supports and the form worked fairly well with the users tested. The most successful pieces for bathing and showering include the front support to help lower and raise (bath), the front support to walk in, the front support to wash feet, the foot rest to wash feet, the vertical grab bars for entering and exiting, and the grab bars that surrounded the round form (shower). Many users also used the footrest for general comfort when they were not soaping.

The general user consensus was that this is a product that has considered all the minute

details of the user, and something like this is needed and well appreciated. The users did not use assistive technology on a daily basis, most used grab-bars and tub benches, and if they had limited mobility issues that were transient (ex. some users occasionally would lose control in their legs, or would get dizzy and lose balance). These users might not think to buy the needed assistive technology or never get around to it, but on a day they are feeling less mobile , it could be present a potential risk for falling. So while this user group would use it, they would not go out of the way to purchase and install if it wasn't already there. For this particular user group, this product at a hotel or health club would be ideal.

Future implications

Mechanisms can further be developed to create a functioning prototype at a lower cost than previously mentioned benchmark products. Due to its large size, installation of the product would need to be considered, as well as some missing factors from the final tub design (i.e., door and faucet). Integration of the rounded form into standard building construction (i.e. flat surfaces and right angles) also needs further consideration. For future tests, this study would benefit from testing users who use wheelchairs, walkers, and testing different age groups. Unfortunately, it was difficult to recruit users with more limited mobility issues due to logistical concerns. If further usability testing were to be performed with users who use assistive technology it is recommended that the prototype be portable.

APPENDIX A

INFORMAL EXPERT INTERVIEW

1. Give the Personas to the Expert
2. Show Storyboard to the Expert
3. Ask Questions About Each Persona

Mike's Questions:

1. Based on Mike's physical limitations let's discuss how the tub assists or prohibits him from transferring in the tub. Is there anything you would me to clarify about the tub or Mike?

2. SLIDE 5: There is an additional slider add on- that can be removed from the outside of the tub. Do you think this would aid Mike in transferring in and out.

3. SLIDE 6: There is a large button for the user to push to close the door, what do you think of the placement in relation to their body, e.g. height, to the side. Is this a placement going to be a problem if they are paralyzed on one side? Where do you think is an ideal location?

4. SLIDE 7: Do you think this opening/closing movement of the tub would scare certain users?

5. Mike is using a toe-tap drain. Do you think Mike would have enough strength to use this? What if this was a normal drain? Do you know of any other solutions if a user cannot physical reach the drain?

6. SLIDE 10: Mike taps the button twice; do you think this is something an amputee can do?

7. SLIDE 11: Mike reaches for the towel in front of him, is this something you think he can do safely?

8. SLIDE 12: Mike makes use the top surface of the inners shell to transfer to laterally transfer to his wheelchair. Is this a safe or user-friendly option?

9. Is there another way that you think Mike would transfer?

Ruby's Questions:

1. Based on Ruby's physical limitations let's discuss how the tub assists or prohibits him from transferring in the tub. Is there anything you would me to clarify about the tub or Ruby?

APPENDIX A

2. Is a 5" inch step height going to impede for Ruby entering? Is there a minimum height that that would still allow Ruby to enter and exit easily?
3. What do you think about the placement or function of the cubby for shampoo?

4. Does it make sense that the button must be pressed twice?

5. While Ruby turns, is the tub an adequate support?

George's Questions:

1. Based on George's physical limitations let's discuss how the tub assists or prohibits him from transferring in the tub. Is there anything you would me to clarify about the tub or Ruby?

2. Is the placement for the button to raise the seat awkward?

3. Do you think George is transferring correctly? How else might he do it? Is there anything about the tub that is blocking his way? Is the form of the tub awkward for George to enter?

4. SLIDE 8: Does George seem to be transferring correctly? Do you have any worries concerning his transferring? Does being paralyzed on one side affect his transferring?

5. SLIDE 10: Does the location of the towels seem appropriate?

APPENDIX B

Guide Usability Testing Prototype 1

Pre-test arrangements (5 minutes)
Have the participant:
Review and sign nondisclosures and recording permissions

Introduction to the session (2 minutes)
Discuss:
This bathtub's purpose is to allow everybody take a shower, particularly older adults and those with limited mobility. Some of the features of the tub is the integrated shelf and bars, very small height to walk over, and that a person can take a sitting bath. We do not have a door at the moment, but please imagine a sliding door that opens and close with a push of a button.

I will be the moderator today. I will first ask you about your bathing experience, and then ask you to do some tasks while bathing, and ask some questions pertaining to the task after each task. Then, I will repeat this with the shower. Afterwards, there will be some more questions and then we will be done.

Background Questions (10 minutes)

1. What is your age?

_____

Please tell me about your bathing situation
Do you take baths?
Do you take showers?
And if you shower, is it in a bathtub or a shower stall?

1. Do you find it hard to entering a regular tub?

No, not likely at all	No, not likely	Unsure	Yes, somewhat likely	Yes, very likely

1. Do you find it hard to entering a regular tub?

No, not likely at all	No, not likely	Unsure	Yes, somewhat likely	Yes, very likely

2. Please explain:

_____
_____

3. Do you have any limited motilities or any surgeries lately?
4. Please explain:

_____
_____

APPENDIX B

5. Do you use assistive technology (e.g. walker, wheelchair)?
6. Please explain:

_____
_____

7. Do you use objects to assist you with entering and exiting the tub (e.g. tub bench, grab bar, tub lift)?
8. Please explain:

_____
_____

Tasks (20 minutes)

Now we will begin the bath tasks, please bear with me as the questions might seem a bit silly: I'm going to ask you to conduct a task, and then I will ask you to rate how difficult the task is compared to what you use at home on a scale of 1-5, 1 being easy and 5 being difficult . This is a casual testing, so please share thoughts or questions you may have.

BATH

Error		Success		Questions
1. Enter the Tub				
1. Fail Task		5. Finish Task		On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to enter the tub compared to what you use at home? 1 2 3 4 5 Would you add any support to assist you exit?
2		6. Touch Bar/texture		
3. Arms touch Wall				
4. Fail to reach intended item				
2. Hit Toe-Tap				On a scale of 1-5, 1 being easy and 5 being hard, how difficult is it to close the drain compared to what you use at home? 1 2 3 4 5 Where would you put this ?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms Touch Wall				
4. Fail to reach intended item				
3. Touch button to close door				Would you prefer to physically close a door or prefer an electric door? Where would you put this
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		

3. Arms touch Wall				button?
4. Fail to reach intended item				
4. Please turn on the water and sustain for 5 seconds				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to turn on the water compared to what you use at home? 1 2 3 4 5 Is there somewhere else you put this?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach on				
5. Please pretend to soap				
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				
5. Grab soap and put it back				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 On a scale of 1-5, 1 being useful and 5 being not useful, how useful would you say the shelf is ? 1 2 3 4 5 how useful would you say the bar is? 1 2 3 4 5
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				
6. Please pretend to soap arms and legs (give orange sponge)				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 In order to wash better, would you like a step to lift your legs?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				
Error		Success		Questions
7. Press the on/off button to close the drain				

1. Fail Task		5. Finish Task		On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 Do you prefer toe-tap or the drain? Where would you put this button?
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				
8. Please Grab the Towel, and put it back				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 Please put the towel anywhere you would like?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms Touch Wall				
4. Fail to reach intended item				
9. Please exit tub				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 Is there anything that is in your way? Would you add any support to assist you exit?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				

SHOWER

Error		Success		Questions
1. Enter the Tub				
1. Fail Task		5. Finish Task		On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to enter the tub compared to what you use at home? 1 2 3 4 5 Would you add any support to
2		6. Touch Bar/texture		
3. Arms touch Wall				
4. Fail to reach intended item				
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch		

		Bar/Shelf		assist you exit?
3. Arms Touch Wall				
4. Fail to reach intended item				
4. Please turn on the water and sustain for 5 seconds				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to turn on the water compared to what you use at home? 1 2 3 4 5 Is there somewhere else you put this?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach on				
5. Please pretend to soap				
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				
5. Grab soap and put it back				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 On a scale of 1-5, 1 being useful and 5 being not usefeul, how useful would you say the shelf is ? 1 2 3 4 5 how useful would you say the bar is? 1 2 3 4 5
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				
6. Please pretend to soap arms and legs (give orange sponge)				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 In order to wash better, would you like a step to lift your legs?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				

Error		Success		Questions
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				
8. Please Grab the Towel, and put it back				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 Please put the towel anywhere you would like?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms Touch Wall				
4. Fail to reach intended item				
9. Please exit tub				On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to do this task compared to what you do at home? 1 2 3 4 5 Is there anything that is in your way? Would you add any support to assist you exit?
1. Fail Task		5. Finish Task		
2. Do legs hit anything		6. Touch Bar/Shelf		
3. Arms touch Wall				
4. Fail to reach intended item				

Where else would you put the shower head?

When entering the shower? Where would you naturally like to face?

Any other supports you would like?

Any other accessory items you would like?

Would you prefer tile or plastic for this tub?

APPENDIX B

Discussions

1. Do you find that this product improves your bathing?

No, not likely at all	*No, not likely*	*Unsure*	*Yes, somewhat likely*	*Yes, very likely*

1. Please explain:

_____
_____

2. How comfortable would you say this product is?

No, not likely at all	*No, not likely*	*Unsure*	*Yes, somewhat likely*	*Yes, very likely*

3. Do you see yourself using this product now or in the future?

No, not likely at all	*No, not likely*	*Unsure*	*Yes, somewhat likely*	*Yes, very likely*

4. Is there anything you think could improve the comfort of the object?

_____
_____

5. What are your thoughts on the overall design?

_____
_____

6. What do you think works well?

_____
_____

7. What would you like to see done differently?

_____
_____

8. Do you have any questions for me?

Thank you, this concludes the usability testing.
User Study

APPENDIX C

Pre-test arrangements (5 minutes)
Have the participant:
Review and sign nondisclosures and recording permissions

Introduction to the session (2 minutes)
Discuss:
This bathtub's purpose is to allow everybody take a shower, particularly older adults and those with limited mobility. Some of the features of the tub is the integrated shelf and bars, very small height to walk over, and that a person can take a sitting bath. Please imagine that the seat will be able to rise and lower. The water will be at chest height. And there is a sliding door.

Background Questions (10 minutes)

1. What is your age?

_____

Please tell me a little about your bathing and or showering ritual:

2. Do you take baths or showers?

baths	*showers*

3. And if you shower, is it in a bathtub or a shower stall?

bathtub	*Shower stall*

4. *Do you ever find it hard to entering a regular tub?*

Yes, extremely difficult	*Yes, somewhat difficult*	*Neutral*	*No, somewhat easy*	*No, very easy*

5. Do you ever find it hard entering a regular shower?

Yes, extremely difficult	*Yes, somewhat difficult*	*Neutral*	*No, somewhat easy*	*No, very easy*

6. Do ever have any trouble getting up and down from a chair or walking?

Never	*Occasionally*	*Always*	*Yes, sometimes*

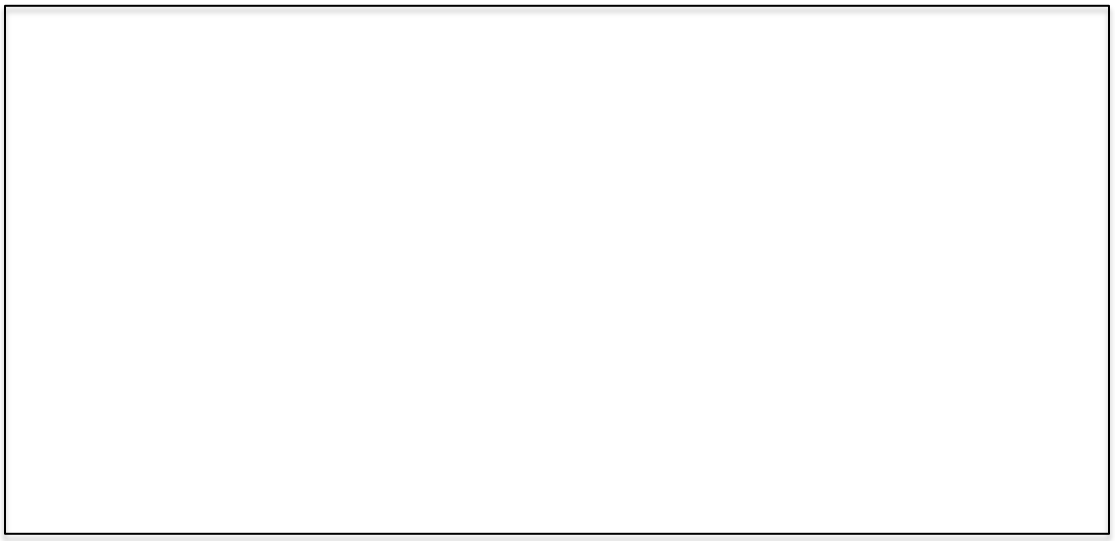
7. Do you have any limited mobility?
   Yes no

8. Do you use assistive technology (e.g. walker, wheelchair)?
   Yes no

9. Do you use objects to assist you with entering and exiting the tub (e.g. tub bench, grab bar, tub lift)?
   Yes no

   grab bar #_____ tub bench

I



10. If so, please draw where the objects are:

APPENDIX C

Tasks (20 minutes)

Now we will begin the bath tasks, please bear with me as the questions might seem a bit silly: I'm going to ask you to conduct a task, and then I will ask you to rate how difficult the task is compared to what you use at home on a scale of 1-5, 1 being easier, 3 being the same, and 5 being harder. This is a casual testing, so please share thoughts or questions you may have.

I'll have you do 7 tasks. Regardless if you usually shower or bath, please compare this situation to if you were taking a bath at your home. Now let's get started.

On a scale of 1-5, 1 being very easy and 5 being very hard, how difficult was it to _____ (task) compared to what you use at home?

Tasks	Rating	Touches	**Where would you put this ?**	Suggestions
Enter Tub				Would you add any support to assist you exit? Yes no How useful would you say the bar is to enter? 1 2 3 4 5
Hit Toe-Tap Drain				

Touch button to close door				Do you prefer a sliding door or a door that opens out?
Please turn on water and sustain for 5 seconds				
Please place the soap where you would put it and pretend to arms and legs				On a scale of 1-5, 1 being useful and 5 being not useful, how useful would you say the shelf is ? 1 2 3 4 5 How useful would you say the side is? 1 2 3 4 5

				How useful would you say the bar is? 1 2 3 4 5
Press on/off button to close the drain			water drain door	Do you prefer toe-tap or the drain button? Would you keep the water controls and buttons together? Would you like to see any of the buttons place elsewhere?

Please exit the tub				Is there anything that is in your way? Would you add any support to assist you exit?

APPENDIX C

I'll have you do 4 tasks. Regardless if you usually shower or bath, please compare this situation to if you were taking a shower at your home. Now let's get started.

On a scale of 1-5, 1 being easy and 5 being hard, how difficult was it to _____ (task) compared to what you use at home?

Tasks	Rating	Touches	**Where would you put this ?**	Suggestions
Enter the Shower				Would you add any support to assist you exit? Yes no How useful would you say the bar is to enter? 1 2 3 4 5
Please turn on water and sustain for 5 seconds				

Please place the soap where you would put it and pretend to arms and legs				On a scale of 1-5, 1 being useful and 5 being not useful, how useful would you say the shelf is ? 1 2 3 4 5 How useful would you say the side is? 1 2 3 4 5 How useful would you say the bar is? 1 2 3 4 5 Please see the sketch: Would you prefer it if the support was more like an integrated bar shelf or more bar like?

				shelf bar

Please exit the tub				Is there anything that is in your way? Would you add any support to assist you exit?

Where else would you put the showerhead?

Where would you naturally like to face?

Any other supports you would like?

On a scale of 1-5 How much do you like or dislike a sitting bath compared to your normal bath?

How do you feel about the seat being able to lower or rise?

Any material preference? Do you prefer tile or plastic for this tub?

APPENDIX C

Discussions

9. Do you find that this product improves your bathing experience?

No, not likely at all	No, not likely	Unsure	Yes, somewhat likely	Yes, very likely

10. Do you find that this product improves your bathing shower experience ?

No, not likely at all	No, not likely	Unsure	Yes, somewhat likely	Yes, very likely

11. How comfortable would you say this product is as a bathtub?

No, not likely at all	No, not likely	Unsure	Yes, somewhat likely	Yes, very likely

12. How comfortable would you say this product is as a shower?

No, not likely at all	No, not likely	Unsure	Yes, somewhat likely	Yes, very likely

13. Do you see yourself using this product now or in the future?

No, not likely at all	No, not likely	Unsure	Yes, somewhat likely	Yes, very likely

14. Would you use this as a shower or a bath?

15. Is there anything you think could improve the comfort of the object?

16. Is there any thing you would change about the shape of the tub?

17. Is there anything you would change about the size of the tub?

18. What your thoughts on the overall design?

19. What do you think works well?

20. What would you like to see done differently?

APPENDIX C

21. Do you have any questions for me?

Thank you, this concludes the usability testing.
User Study

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